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NOTE—In this Index the names of authors of papers are printed in SMALL CAPITALS and the titles of papers in *italics*. References to special information in papers or discussions are indicated by bracketed page numbers.

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PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXIV FEBRUARY, 1908 No. 1

ANNUAL MEETING.

January 21st, 1908.

President J. K. Lyons

In the Chair.

THE ALTERNATING CURRENT RAILWAY MOTOR.

Address by S. M. Kintner,*

Retiring President.

The use of alternating current as a means of distributing power electrically is the generally recognized standard practice. The ease with which it can be changed from one pressure to another makes it particularly applicable for distribution at high pressure and application at any desired pressure. The high efficiency of the pressure changing devices, or transformers as they are generally called, together with the fact that they have no moving parts and consequently require no attendance, makes their operation very economical. Power is being distributed and used as alternating current at the point of application in a number of industries, particularly the lighting and industrial power applications. In this last class of service induction motors, and in some instances synchronous motors have given very general satisfaction.

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* Electrical Engineer, Westinghouse Electrical and Manufacturing Company.

The direct current railway systems have recognized the advantages of alternating current distribution and have in a large number of instances developed and distributed their power in this manner. Unfortunately, there is no way of changing from alternating to direct current, or vice versa, except by passing it through some rotating machine. This condition makes it necessary to have attendance constantly and also adds to the losses of power in the distribution. Even with this adverse condition, the alternating current with its sub-stations containing rotating machines, is more economical than direct current distribution, at the low pressures in use, with the enormous amount of copper required in the feeder systems. If the direct current could be changed from one pressure to another as readily as the alternating, and thus allow a high pressure distribution and low pressure application, there would be little demand for the alternating current. As, however, this is impossible, excepting through the use of machines with rotating parts, and as machines for handling high voltage direct current are in themselves quite sensitive and troublesome, it is evident that recourse must be had to the alternating current. It is the necessity of a double transformation, that is from high pressure alternating to low pressure alternating by means of transformers, and then again from low pressure alternating to direct current by means of motor-generators, or rotary converters, that serves as a thorn in the flesh of engineers. The losses involved in this double transformation and particularly those incident to the continuous operation of the transforming and converting apparatus which must of necessity be operating at very low efficiency at times, form quite a large part of the total power losses of a day's operation. In those railway systems operating cars over considerable lengths of line, and particularly those having few cars, the sub-station power losses and cost of attendance is quite a serious matter.

The low voltage collection of power becomes quite troublesome as the larger amounts are required, and at comparatively small ratings it is necessary to abandon the trolley and

use the third rail. It serves, of course, to give still larger capacities, but as the size of equipments is increased, the third rail method of power collection will soon reach its limit.

Summarizing, it can be said then that the alternating current railway shows considerable improvement over the direct current railway in the following points:

(1) More economical distribution of power—both in first cost and in operation.

(2) Lends itself to collection of large amounts of power from an overhead wire or similar structure.

A third point can be added for most alternating current systems and that is, more economical control—it being possible to operate economically at a number of different speeds.

MOTOR CHARACTERISTICS.

Experience in direct current railway work has shown that a particular motor characteristic, of the series motor type, better suited to the service than that of any other. In direct current work it is possible to obtain quite a range of motor characteristics, and the fact that this one has shown itself so superior to any other should be accepted as indicating the kind of characteristic that the alternating current railway motor should have. The following performance curve, shown in Figure 1, is that of a standard direct current railway motor of 100 H. P. nominal rating. The present practice in railway motor ratings gives a motor the maximum rating in horse power that it will develop in a shop test when its temperature rise is less than 75° C. at the end of one hour's operation. Referring again to the performance curve, Fig. 1, it will be noticed that the motor develops its greatest torque at its lowest speeds, developing its maximum at starting. It should also be noted that a wide variation of line voltage will have but little effect on the torque of the motor, this depending entirely upon the current. The voltage variation will, however, affect the motor speed. On account of the enormous torque developed at starting, it is generally necessary to employ a starting resistance.

It will be seen from the curve that as the motor speeds up, the torque falls off—it is thus evident that at some particular speed the torque developed will just equal that required to overcome the friction and windage of the car. This speed cannot be exceeded then with this equipment on the same track and line voltage conditions.

Horse power rating on a motor of this type counts for very little. The points that are important are the torque it will develop, the maximum permissible speed, the current it will carry safely for periods of one hour or so without excessive temperature rises, and a continuous current rating with the same temperature conditions.

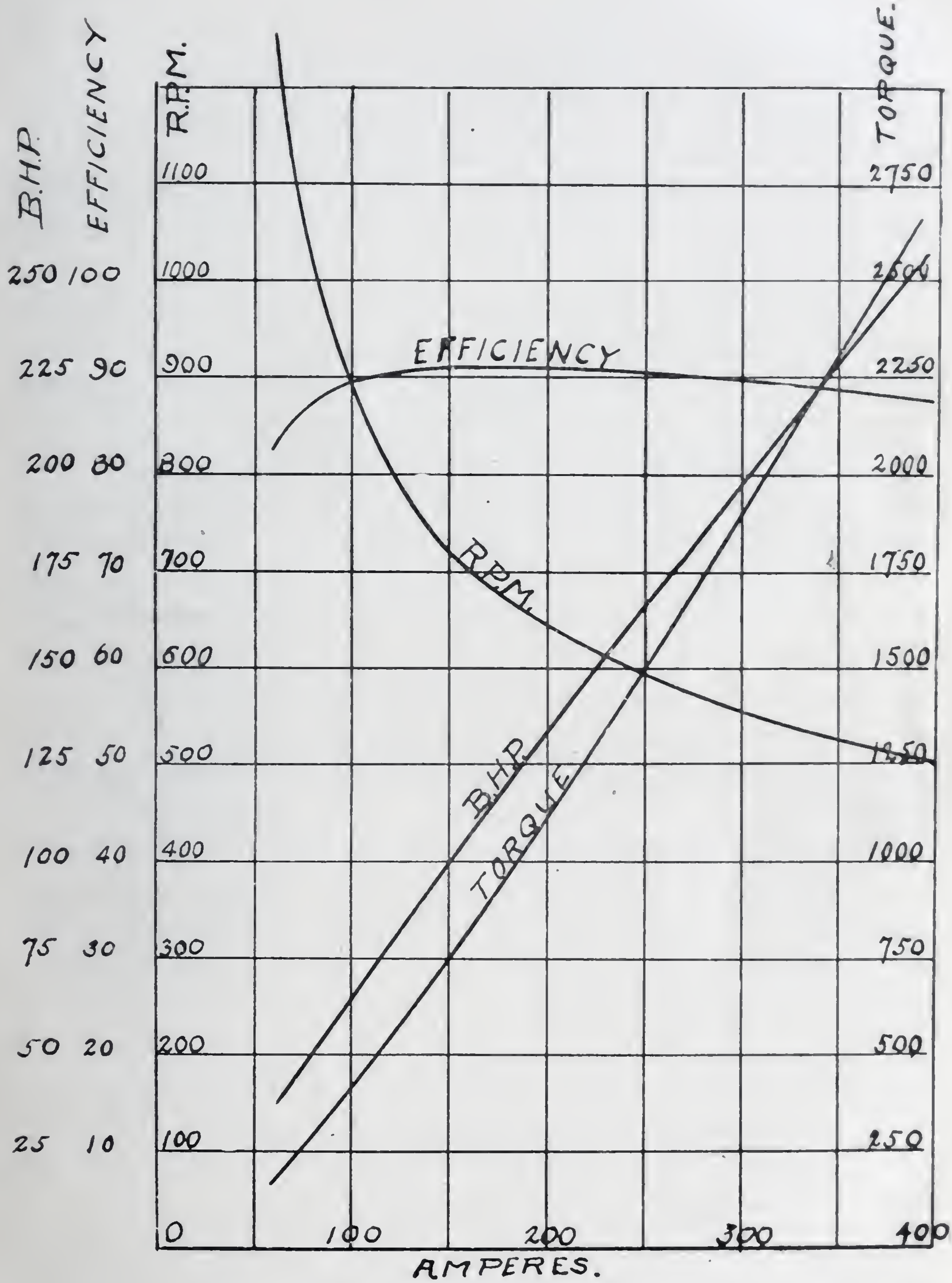
Three distinct types of alternating current motors have been proposed for railway service. They are mentioned here in the inverse order of their relative importance:

First—Synchronous motors.

Second—Polyphase induction motors.

Third—Single-phase series motors.

The synchronous motors have been expected to run continuously at constant speed and some means of power transmission from the motor to the car wheels has been proposed. A synchronous motor driving a direct current dynamo which in turn is connected to motors mounted on the car axles, has been urged for a number of years. This system is defective, first from the standpoint of weight; second, complication; third, the difficulty of keeping a synchronous piece of machinery in operation under such conditions. Another system based on the same general principles contemplated the use of air compressors driven by a synchronous motor. The devices were arranged so that when the locomotive was standing still the compressors would fill certain storage tanks with air, which could later be used to assist the synchronous motor drive the car by employing the air compressors as air engines and discharging the tanks through them. This system is subject to the same general criticisms as that mentioned above. Neither of these has ever been placed in actual commercial service to my knowledge.



B.H.P.
EFFICIENCY
R.P.M.
TORQUE.
EFFICIENCY
R.P.M.
B.H.P.
TORQUE
AMPERES.
250 100
225 90
200 80
175 70
150 60
125 50
100 40
75 30
50 20
25 10
1100
1000
900
800
700
600
500
400
300
200
100
0
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
100
200
300
400

FIG I

Polyphase motors have been condemned by American engineers insofar as railway service is concerned, for two good reasons: First, improper speed-torque characteristic; second, the requirement of two insulated overhead conductors in place of one, as at present in direct current practice.

The induction motor is inherently a practically constant speed machine and corresponds to the shunt motor in direct current practice.

The following performance curves, Fig. 2, show a typical induction motor characteristic, which will be seen to depart quite widely from that shown in Fig. 1, which has been found very satisfactory. The induction motor, unless complicated by special windings which change the number of poles, has but one speed. It is possible to get a half-speed by a cascade connection of two motors on the same car. Motors of this type can be built so as to be very rugged mechanically, as they have no commutator, and it is to be regreted that their characteristics unfit them for the service. European engineers are using motors of this type to a limited extent and are having a fair degree of satisfaction. The places where they are operating successfully are, however, those with particularly favorable conditions.

Single-phase series motors are the ones that seem to be most promising. They have characteristics that quite closely approximate those of the direct current series motor. Also like the direct current motor, they require but one overhead trolley, or collecting device.

Fig. 3 shows the performance of a 25 cycle 100 H. P. motor. It will be noted at once that the alternating current motor is operating at a considerably lower voltage than the direct current motor—this is for a reason that will be stated later in this paper. This lower voltage does not make any particular difference in the case of the alternating current motor, as a transformer is carried on the car anyway and the voltage can be made any value to suit the motor. It will be noticed also that the speed curve is steeper than in Fig. 1. This is on account of the alternating current motor's power

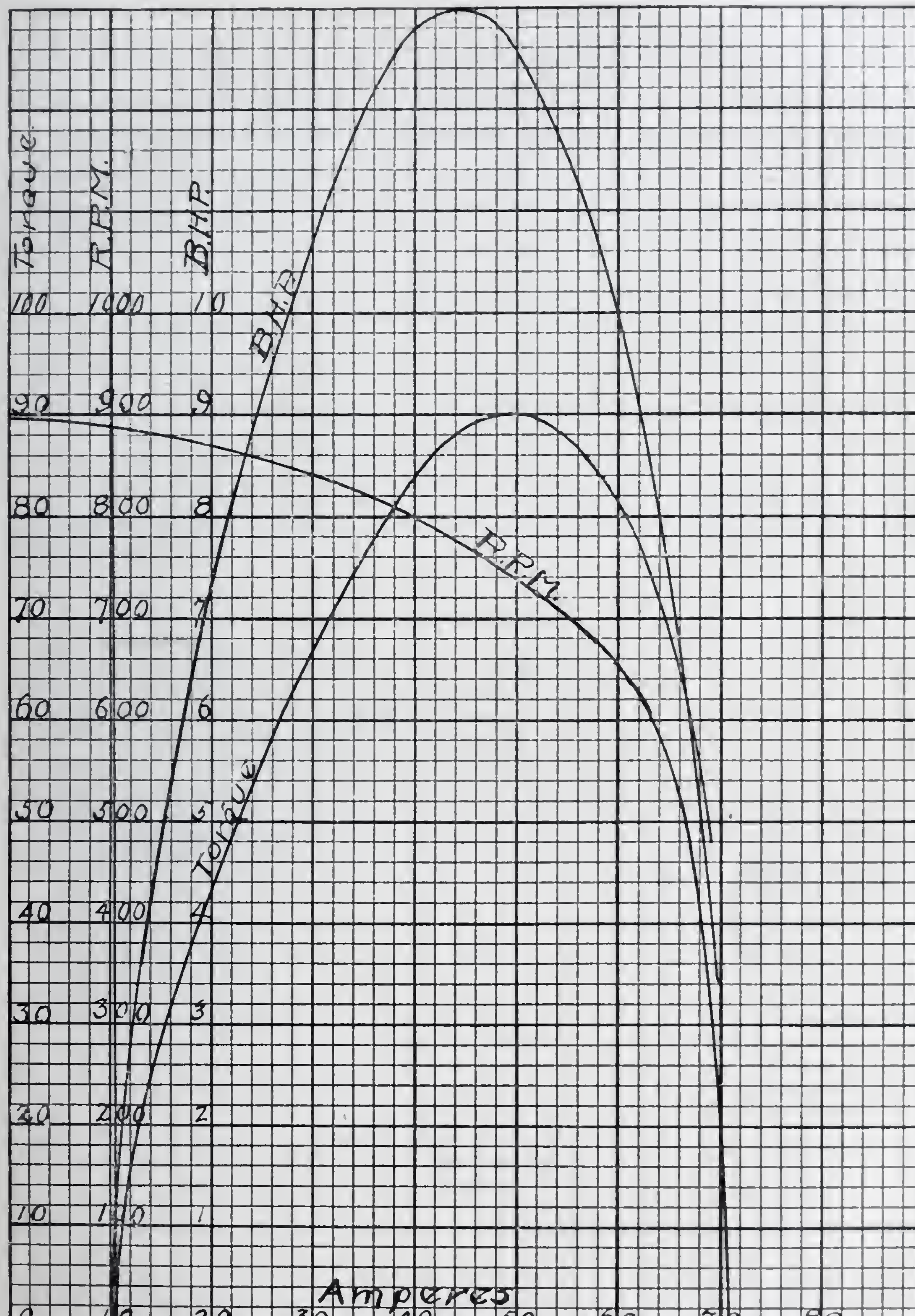


FIG. 2.

factor and again on account of lack of saturation in the iron. The motor efficiency is in general somewhat less than that of a corresponding size of direct current motor. This slight difference is more than compensated for in the reduced losses of the control in the alternating current motors in a large number of cases, and in any event, is of but slight importance in view of the saving of losses on the line and sub-stations from that common in direct current systems.

The single-phase series motor is but a refined direct current series motor to enable it to operate satisfactorily on alternating current. Its performance, when examined from the

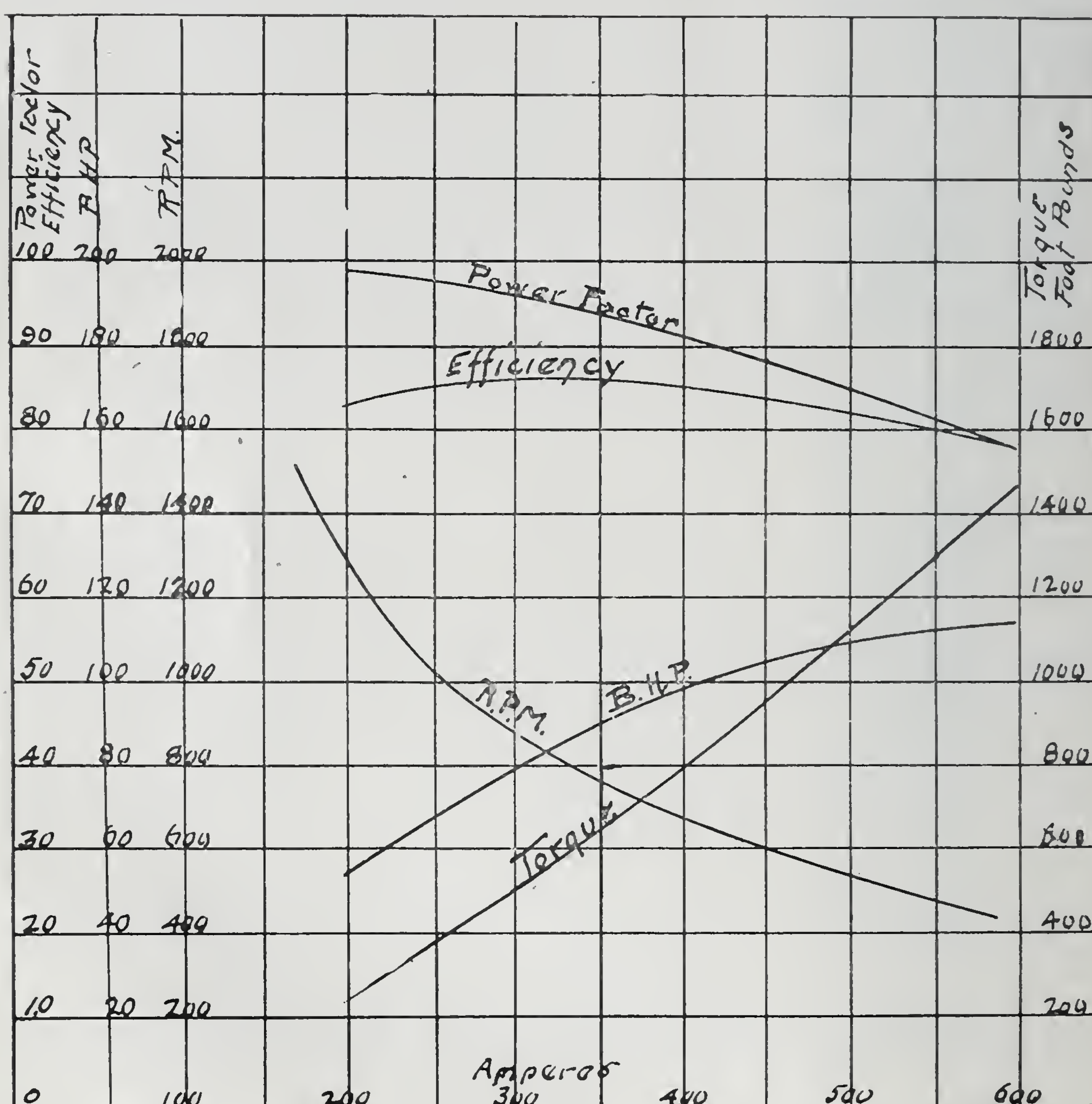


FIG. 3.

motor point of view only, is better on direct current than on alternating, but then no claims of superiority in the motor have been made for the alternating current.

It has been known for years that any direct current series motor would operate on alternating current. The direction of rotation depends only upon the relative directions of current and magnetic flux, and as these change simultaneously in the series motor, the armature continues to rotate in the same direction, regardless of the frequency of change in the current. While the above condition is true theoretically, and can be demonstrated by test, there are certain difficulties in the way of such an operation which makes it impracticable for actual service. The three principal difficulties are the following: First, excessive iron losses in the solid cast structure of the field of the motor; second, excessive inductive voltage in the field and armature windings, which give the motor a very bad power factor; third, very poor commutation, the brushes sparking viciously, and wearing away at a rapid rate.

Discussing the above troubles in the order named: The trouble from excessive iron loss has been overcome by laminating the magnetic part of the field structure in a manner similar to that of the armature. This has reduced the loss to a reasonable amount, below which it is not possible to make a very great gain with the present available magnetic sheet steels.

The second trouble, bad power factor, has also been very materially relieved by a form of compensating winding. Before describing this winding, a word about power factor may be of interest. The power factor of any circuit is the ratio of the true kilowatts to the apparent kilowatts, the two being the same when unity power factor exists. The difference between the true and apparent kilowatts of a circuit is caused by the voltage and current being out of phase with each other, so that they cannot work to best advantage. It is equivalent to two forces acting at an angle to each other at their point of application. The resultant force is less than the numerical sum of the two in such a case. The same is true of the two electrical components of power. A low power factor is bad for a motor

because it may not get enough current to give it the necessary torque to start if the line voltage should happen to be too low. It is bad for the system because it requires larger transformers and generators and increased losses in them.

The compensating winding is in reality a second armature winding, but it is placed on the stationary element as near to the armature as it can be supported. It is connected so as to oppose all magnetic action of the armature, and, as a result, greatly reduces the inductive voltage of the armature. It has no effect on the main field circuit, which still remains as inductive as ever, insofar as the compensating winding is concerned, directly. It does assist to reduce the inductive volts in the field by allowing the use of a very small air gap and consequently reduced number of turns on the field. This small gap in connection with the smaller number of field turns and a reduced magnetic flux all tend towards an improved power-factor.

The diagrams in Figure 4 show the method of connecting the various circuits. The figure to the left is the straight series motor having main field winding F, armature A, and compensating winding C, all in straight series relation. The middle figure has its armature A and main field F in series and the compensating winding C is short-circuited upon itself and derives its current by induction from the armature. It must therefore of necessity be weaker than the armature, as otherwise it would receive no power from it, and consequently does not entirely neutralize the armature inductive action.

The third figure, the one to the right, has its main field F permanently connected in series with the compensating winding C, and the armature derives its current entirely by induction. The armature circuit is closed by short circuiting the brushes. This last arrangement is frequently spoken of as the repulsion motor, but is, as will be seen from the evolution of diagrams in Fig. 4, but a particular form of series motor. It has the same general speed-torque characteristics as the straight series compensated motor. This arrangement has been proposed recently by one of the large American elec-

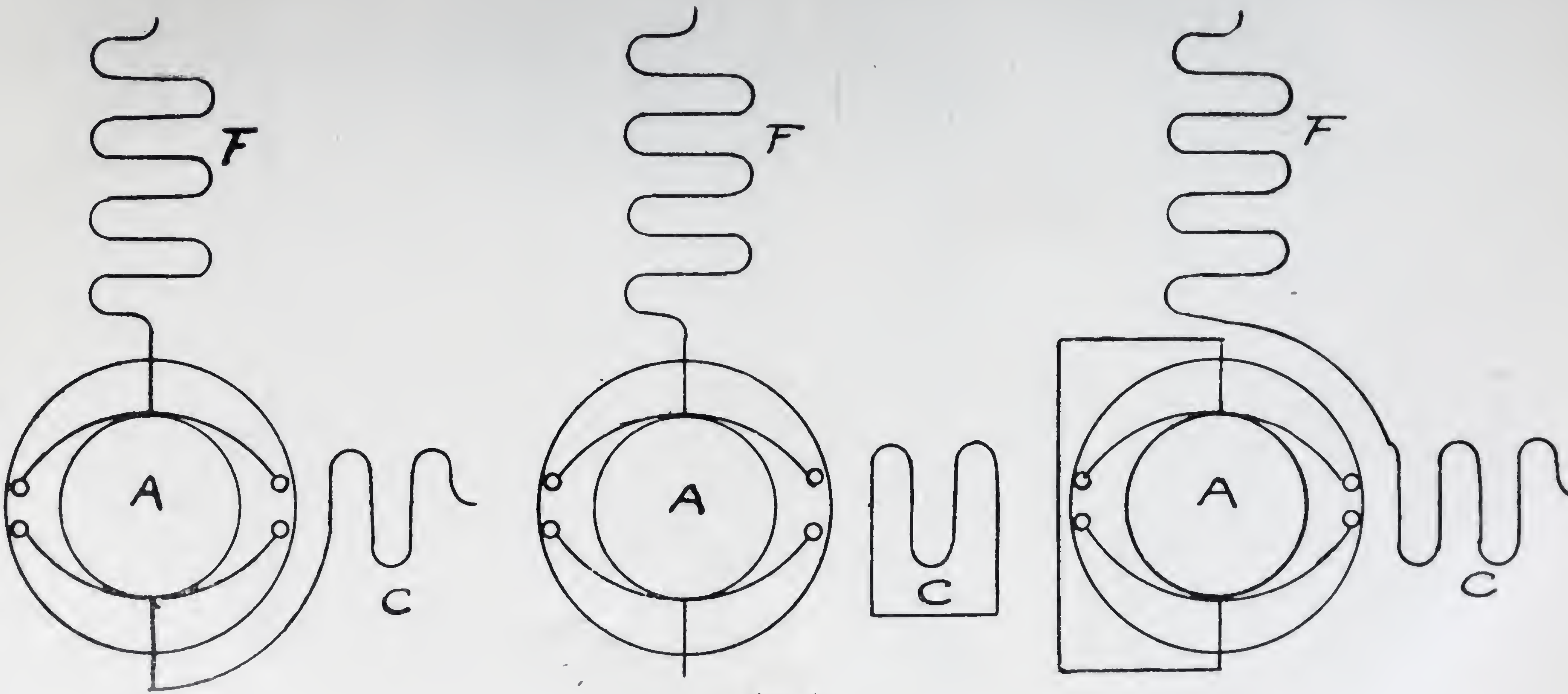


FIG. 4.

trical manufacturers as a ready means of getting an improved starting condition.

In the proposed arrangement, the compensating winding is made double the strength of the armature. The result of this is double current in the armature for a given current in the main field. The real object was to obtain a weak field and large armature current for starting, and could have been accomplished just as well by a series multiple arrangement of the main field winding.

The location of the compensating winding in relation to the other circuits of the machine will be shown in a later diagram.

The trouble with commutation of the single-phase motor is the one that has been the hardest of any to solve. Before taking up various methods proposed for improving commutation, a diagram showing the location of the various essential parts of the motor will be considered.

In Fig. 5 a development of the windings of a 4-pole motor is shown. The main field poles shown in the center of the diagram and marked N and S are supposed to have the value marked, at the instant of consideration. The main field coil windings are not shown, but are simple coils surrounding the various poles and having currents passing in the proper direction to give the polarities indicated at the instant considered. It should be definitely understood that all directions as indicated by arrows on the windings are true only for the particular instant and are changing so as to have continually recurring values at the rate of 25 per second.

The armature winding is a standard multiple winding such as is usually employed on direct current machines, there being two bars per slot, one above the other, across the armature face, as shown in the diagram. The diagram should be used strictly as a diagram, as no effort has been made to get the proper proportion of the various windings. The compensating winding will be seen at the top of the figure where it has been displaced, having been moved upwards directly in a straight line. It will be seen that the currents in its coils are in

direct opposition to those in the armature windings, and the pole that it produces is intended to overpower that produced by the armature windings in those instances where the compensating winding is connected directly in series with the rest of the machine. If short-circuited on itself it will be weaker than the armature, as mentioned before, as in this condition it will simply act as a short-circuited secondary, of which the armature winding is the primary and can therefore never have as many ampere turns as exist on the inducing source, the armature.

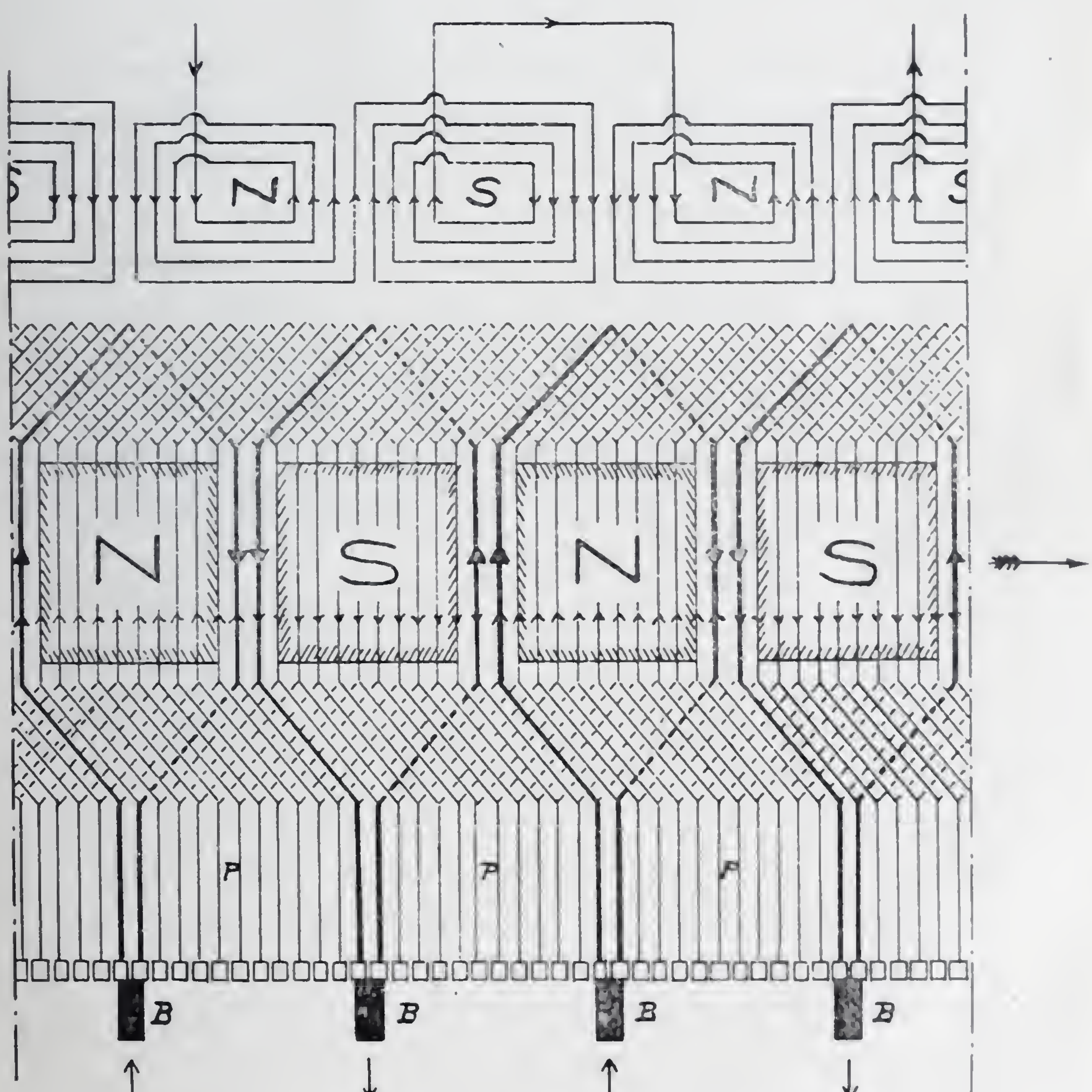


Fig 5

The armature coils shown in the heavy lines will be seen to be short-circuited by the brushes B on the commutator. This coil is also seen to embrace the entire pole and consequently acts like a short-circuited secondary of a transformer as the main field flux varies. The direction of this induced current is indicated by the dark arrow heads. The small arrows on the dark lines indicate the working armature current in that half of the coil immediately above or below the short-circuited coil. The existence of this short-circuit through the carbons is very largely responsible for the bad commutation existing in some types of single-phase series compensated motors.

It will at once be evident that anything tending to increase the magnetic flux or its frequency will increase the short circuit voltage, which will in turn make the commutation worse, due to the increased short-circuit current.

The starting condition of the motor is the most severe one insofar as short-circuit effects are concerned. It is then that the largest currents are taken and consequently strongest fields produced, unless the field is purposely weakened. In addition to this, the same coil is subjected to the action for a greater period of time, as the armature is just starting from rest, and severe heating is most apt to occur then. With this in mind and the further point that the very heavy trains accelerate at the slowest rate, it should be evident that any device for relieving the short-circuit trouble must, in order to be of very much value, take care of the starting and periods of accelleration, as well as those of running.

When the armature is running, the short-circuit current is very materially reduced by the impedance of the circuit of the short-circuited coil. The short-circuited coils undergo a series of interrupted currents applied to each coil for a very small interval of time, and the current never reaches its final value before the circuit is opened by the carbon brush.

A number of attempts have been made to devise windings that would be of such a nature that the short-circuited coil could not exist—as yet none of these has been successful.

Some of them have succeeded in eliminating the short-circuited coil, but have introduced another trouble equally as bad and as hard to cure.

Attempts to use reactance coils located as indicated by the lines P in Fig. 5, connecting the armature winding to the commutator bars and arranged so that the working currents would not be impeded while the short-circuits would, have been more promising in theory than in practice. The space requirements for reactance coils of sufficient size has thus far made this method inoperative.

The use of high resistance carbons has done some good. Some types of machines will operate fairly well with high resistance carbons, that will fail absolutely with low resistance carbons. This practice cannot be recommended for any save small motors, as the brush and commutator wear is very severe.

Attempts have been made to use laminated brushes, the various laminae being connected externally through suitable reactance or resistance. These brushes have not given satisfaction, being very sensitive and liable to injury. No brush of this type has been developed which could in any way be considered more than purely experimental.

The use of preventive leads has proven to date, to be the most satisfactory solution yet devised. These leads are connected between the armature windings and the commutator bars. Only those leads attached to the commutator bars under the carbons are active at any instant. These leads are made of resistance material, such as German silver, and are chosen so as to have a resistance which will give the minimum loss, as it is evident that not only the short-circuit current operates through them, but also the useful or working current.

Motors of this type have given the best account of themselves in actual service under the difficult conditions of acceleration, of any that have been built.

It is possible to introduce a voltage in opposition to the short-circuit voltage by the use of a suitable interpole excited by a current of the proper phase relation. The voltage pro-

duced is effective only when the machine is running and is absolutely useless at start. It requires a very nice adjustment and will then neutralize only a particular value of short-circuit voltage, which is dependent upon one particular value of main field current, and all of this is dependent again upon a certain armature speed. It must be evident, therefore, that only partial neutralization takes place and the carbon brush takes care of the rest.

In a study of the phase relations of the various elements of current, voltage and magnetism, the diagram shown in Fig. 6 will prove of interest.

This diagram is made on the assumption of harmonic variation of current, voltage and flux. It is, of course, well known that the wave forms actually existing are very irregular and will consequently cause certain variations that would not exist if all the values were truly harmonic.

Referring again to the diagram, Fig. 6, let O-θ represent the phase position of the main field flux at a particular instant of time. O-Em represents the phase relation and magnitude of the impressed voltage required to overcome the reactance in the main field. OEs, below the line, represents the magnitude and phase of the voltage produced in the short-circuited armature coil and O Is represents the phase relation and magnitude of the short-circuit current. To find the effect of the short-circuited coil current, this value is compounded with the primary magnetizing current after allowing for iron loss shown as Im, and gives a current value O-I, which is seen to be leading the magnetic flux by a small angle. It should be noted that the effect of the short-circuited coil is to reduce the main field flux for a given current, or to increase the main field current for a given field flux. It should be noted that the more nearly in phase the short-circuit current with the short-circuit voltage, the less effect it has as a disturbing element tending to change the value of the main field flux.

Referring again to the field volts, there is a certain voltage required to overcome the drop in copper resistance. This is in phase with the current and is shown as O Er, another

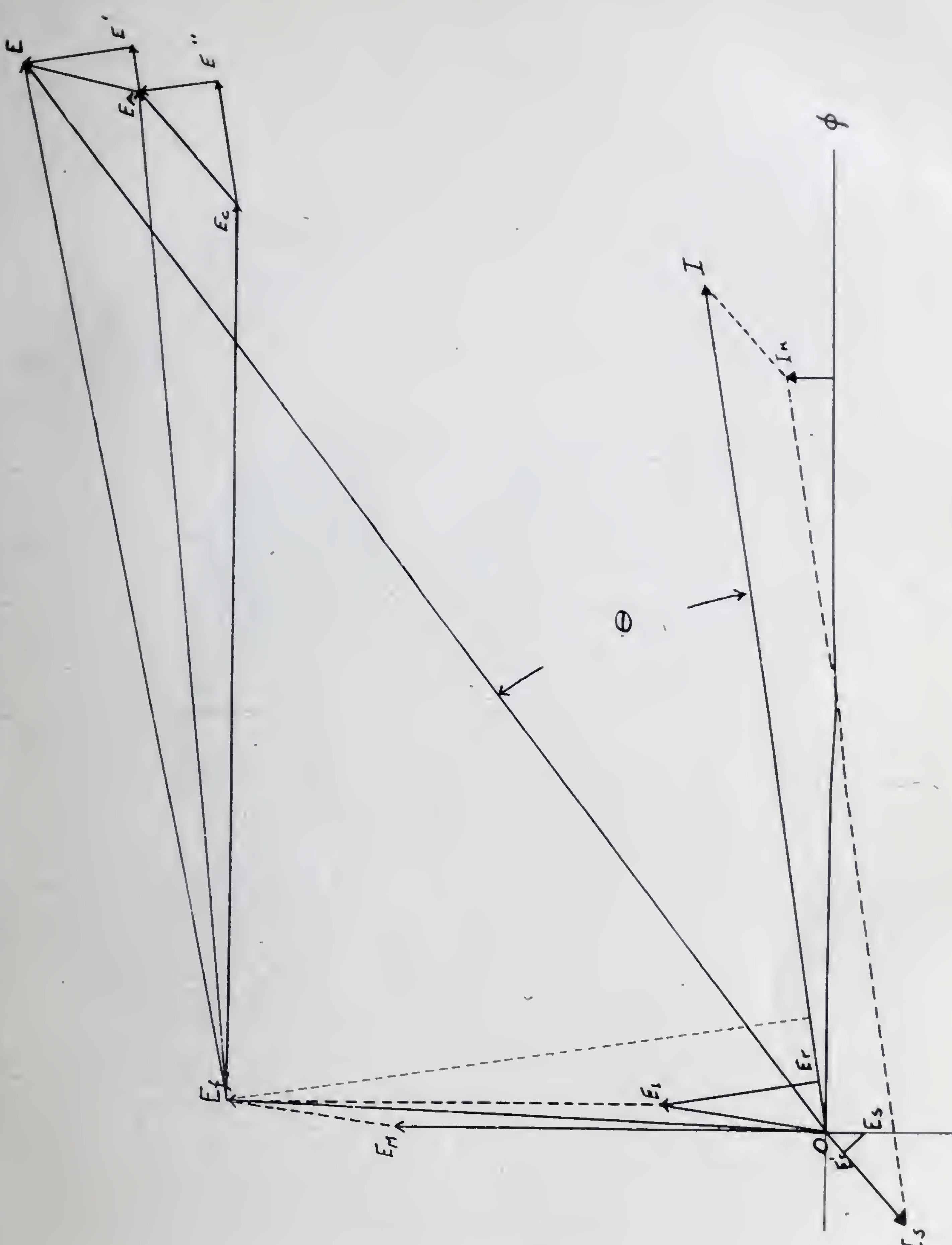


FIG. 6.

voltage needed to overcome inductance due to magnetic leakage in the main field coil, is shown as Ei Er and is at right angles to the current. Compounding these two voltages with O Em, the value of O Ef is obtained. This is the main field O Em, the value of O Ef is obtained. This is the value of the

main field volts and when projected onto the current line, as shown dotted, the part falling between O and the place of contact of the dotted line represents the energy loss volts in the field current. The counter electro-motive force due to armature rotation is shown at Ef-Ec and is in phase with the flux. Ec-E″ represents the lost I R volts in the armature and brushes. E″ Ea represents the inductive volts in the armature. Ea-Ef gives the armature volts. Ea-E′ is the energy loss volts in the compensating winding. E′ E is the inductive volts in the auxiliary. E-Ef is the voltage across armature and compensated winding. E-O is the line volts impressed on the motor. θ represents the angle of lag of the current, back of the voltage, the cosine of θ being the power factor of the whole motor.

It will be seen from the diagram that an improvement in power factor can be obtained by reducing the field volts by reduced frequency or fewer field turns and weaker field. It can also be benefitted by increasing the armature counter volts by increasing the motor speed or by increasing the number of armature conductors. It is, of course, evident that anything tending to keep down the inductive element in the armature and compensating windings will improve the power factor. It is also equally evident that any commutating poles, no matter how arranged, must introduce an inductive element and consequently tend towards a reduction of power factor.

From the diagram, it is seen that the proper phase relation for a commutating pole to wipe out the short-circuit voltage is not that of the main field and consequently this method of producing an interpole for commutation is wrong.

If a voltage be taken from the transformer supplying the motor and applied directly to the commutating poles, the flux will be quite close in phase to the value desired. This shunt arrangement is, however, considerably more complicated and apparently more sensitive in operation than the straight series motor with preventive leads. This sensitiveness is due to the fact that the shunt arranged commutating pole is independent of the motor load or running conditions, excepting

as changes are made by the operator with his control. It is thus possible for the commutating pole to have a constant value while the short-circuit voltage varies over quite a range, due to a change of current in the motor field. The change in motor speed also tends to cause an unbalancing of the voltages of short-circuit and that due to the commutating poles and motor speeds. It is thus evident that per-

FIG. 7.

fect elimination of the short-circuit current exists for only one motor speed and one motor current for each commutating pole strength. It is quite likely, therefore, that a motor of this type may be run on a stand test and give very satisfactory results, and yet in service be subject to a large amount of short-circuit action and consequent heating.

In external appearance the series compensated single phase motor with preventive leads resemble quite closely the ordinary direct current railway motors. In fact, it is quite difficult to tell them from the direct current motors from outside appearance unless one is thoroughly familiar with the special features that distinguish them. Fig. 7 is a photograph of the suspension side of a standard 100 H. P. single phase motor. It has the same rugged mechanical features that characterize direct current railway apparatus. On the left hand side of the figure the extensions from the bearing housing and from the axle cap—used for supporting the gear case—will be seen. The end of the armature shaft upon which the pinion is mounted, this motor being of the geared type, is seen extending slightly beyond the gear case support. At the top and middle of the motor a metal nose—part of the cast steel frame of the motor—is seen extending outward. When mounted on a truck this nose is supported on a bar which is part of the truck, and serves to carry part of the motor weight. The rest of the motor weight is carried on bearings which surround the car axle. Fig. 8 shows the axle bearings and the oil wells used in lubricating them. The right hand axle cap shows the gear case support to which attention was called in the other view. A perforated sheet metal cover will be noticed at the top left hand end of the picture. This protects the commutator from objects falling in, and also allows ample ventilation.

Fig. 9 shows the armature of this same motor. It will be seen to resemble very closely the standard direct current motor armature. It is, in fact, just the same, with the exception of the preventive leads, which are not visible, being in the

bottom of the armature slots, below the copper winding. Otherwise it follows exactly direct current practice.

Fig. 10 shows a view of the interior of the frame, or field of the motor. It is here that it shows its greatest variation from the direct current motor. The heavy cables leading through the frame and extending inwardly are the leads to the

Fig. 8.

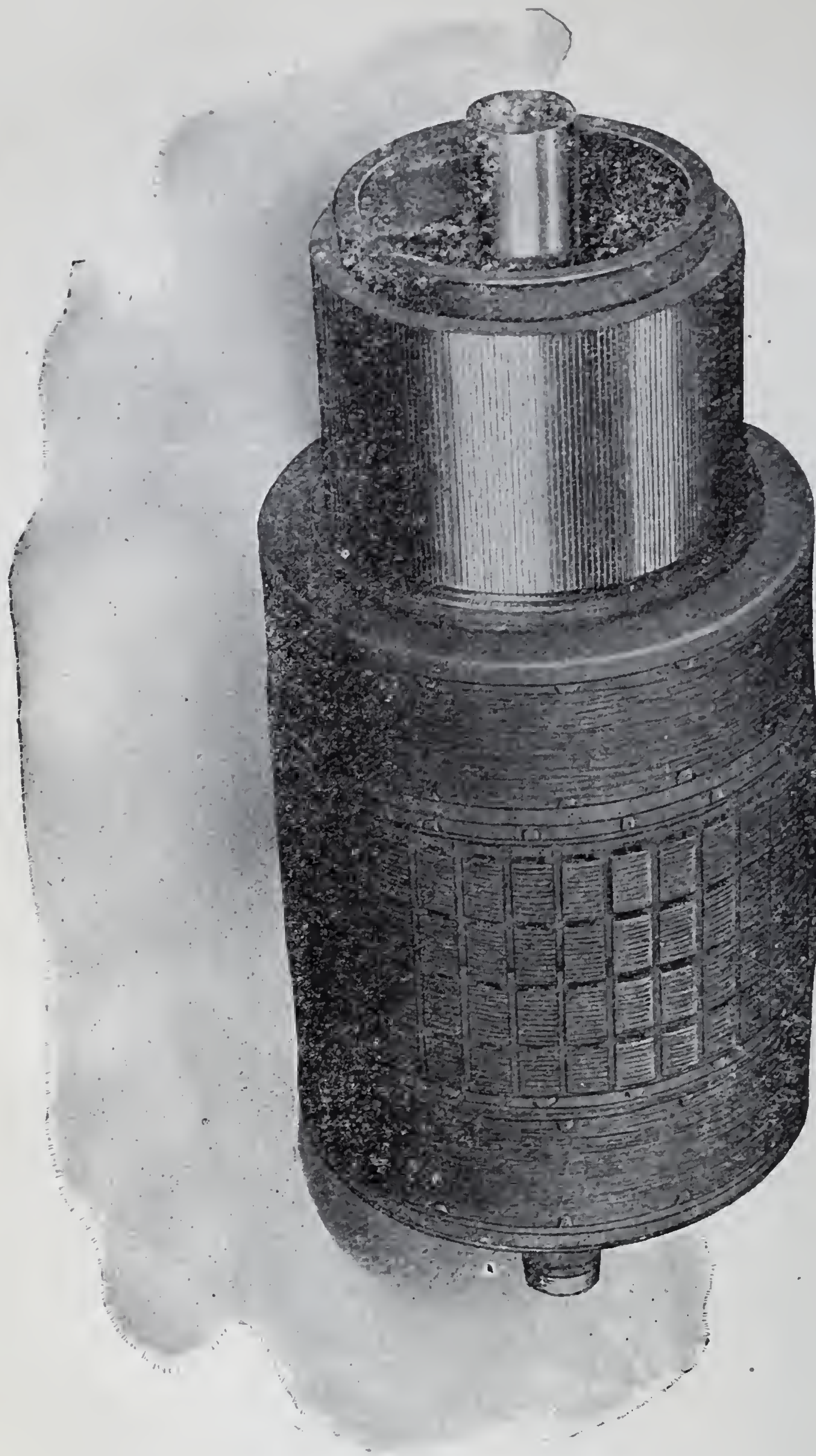


Fig. 9.

motor and connect to the various brush holders, compensating windings, field coils, etc.

The magnetic part of the field circuit is made up of sheet steel which is rigidly supported in the cast steel frame. This lack of ability to use the steel frame for part of the magnetic circuit tends to make the alternating current motor somewhat

heavier than the direct current motor. This motor is a four-pole machine and the slots for supporting the compensating winding shown diagramatically in Fig. 5 at the top, can be seen crossing the face of each of the three poles visible in Fig. 10. This type of motor, while more expensive to build on account of the extra windings, laminated field structure, etc., is not less rugged mechanically. There are hundreds of motors of

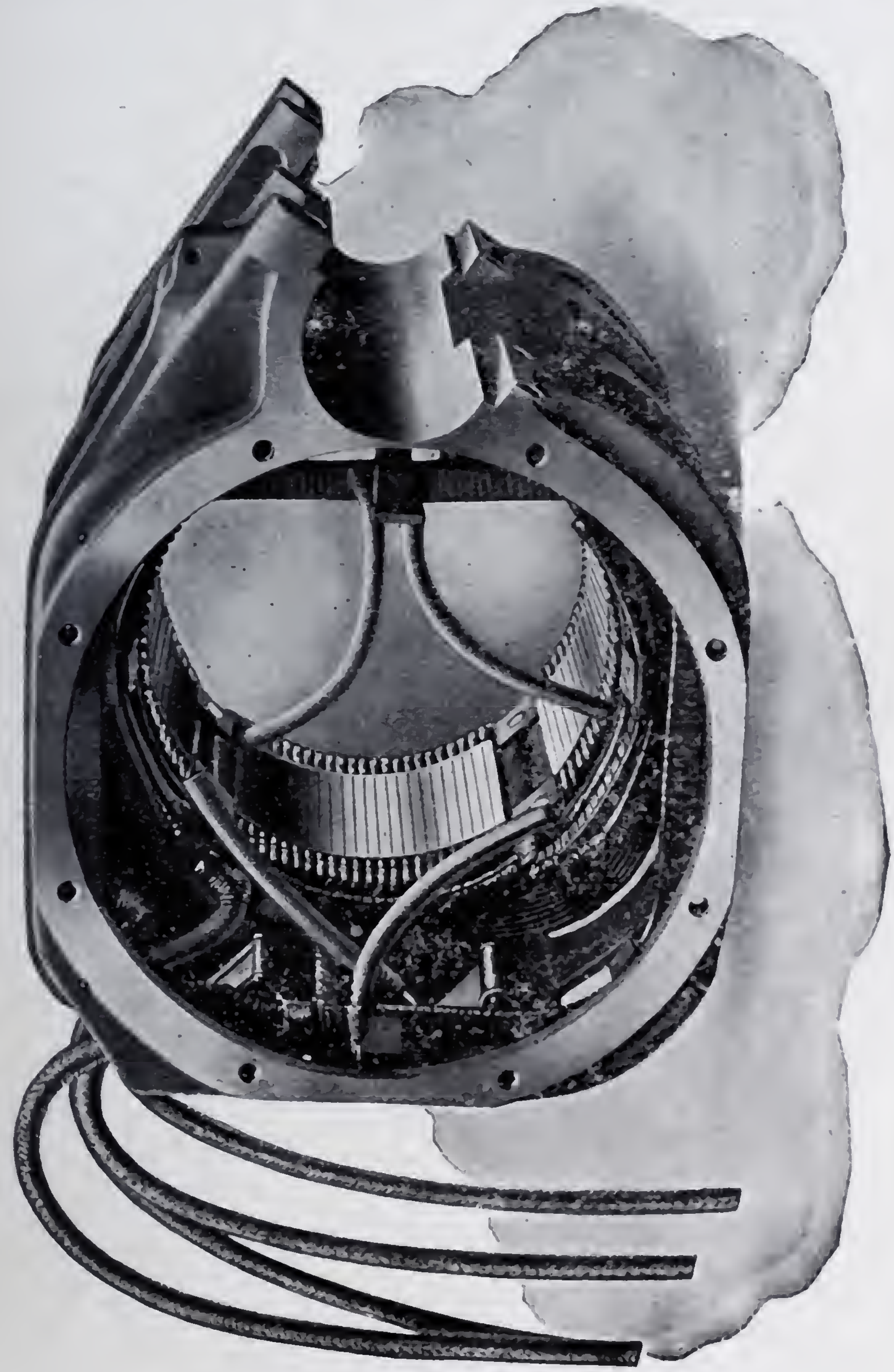


FIG. 10.

this type in service and they are coming up to the most sanguine expectations of their designers. While probably no one is willing to state that this is the ultimate solution of the single phase railway motor problem, this type of motor has reached such a degree of perfection and has demonstrated its ability in actual service so completely, that it must be seriously considered in all railway projects involving any distance of power supply.

This type of motor—either geared or gearless, according to conditions, is at present the one that gives the greatest promise of successful operation under the severe service conditions involved in the electrification of steam railroads.

December 17, 1907.

President S. M. Kintner

In the Chair.

CONTRIBUTIONS OF GLASS

TO OUR KNOWLEDGE OF THE STELLAR UNIVERSE.

By Dr. John A. Brashear,*

Past President.

Mr. President and Gentlemen: I think you made a mistake in having two papers tonight, particularly when there was such a splendid one as Mr. Macbeth has given us. I do not know that there is anybody in this old round world, at least on this side of it, that knows as much about glass as Mr. Macbeth. When you see "Macbeth's pearl top" chimneys you may be sure they are all right.

I have been interested in the subject of glass making and the history of glass for a good many years, and I have no doubt from what Mr. Macbeth has told us that his paper has required long and patient research. You may be certain that the subject is one of the most interesting in the whole realm of science. To think what a little bit of dirt can do, dirt that our dear departed friend, Lord Kelvin, once said, was "only matter in the wrong place." When put in the form of a crystal lens or prism it has opened up new and most marvellously rich fields in the microcosm and macrocosm of the universe. I will take you through my theme with a picture story, and as I have no firstly, secondly or thirdly, if there is anything you wish to know as we go along, do not fail to ask me.

It would be difficult in the short time at my disposal to tell the story of what has been done by the aid of the material we have chosen to name glass. The story of the microscope and what it has revealed in the minutiae of nature would

* Astronomical and Physical Instrument Manufacturer, Pittsburgh, North Side.

FIG. 1. The Nebulae in Orion.

fill volumes. But this story must be left for someone else to tell. I shall ask you to listen for a little time tonight to the story it has told of the universe of stars that surrounds us and what it has revealed as to their nature, their motions and probably their destiny.

NEBULAE.

Long ago it was suggested by the great mathematician LaPlace that the stellar universe has been built up of nebu-

lous matter. The visual telescope had already revealed many nebulae in the heavens, but it remained for the photographic telescope to tell us what the real nature of these nebulae is. A number of them, such as the nebula in Orion, the Dumbell nebula, the Ring nebula of Lyra, the Crab nebula and the great Trifid nebula, were all within the reach of the visual tel-

FIG. 2. The Spiral Nebulae in Ursa Major.

FIG. 3. Great Nebulae in Andromeda.

escope, but only one single one of the spiral nebulae had ever been seen with the greatest visual telescope in existence. But it is now within the power of even the smallest of the photographic telescopes to show thousands of nebulae where tens were visible to the naked eye.

THE PHOTOGRAPHIC AND THE VISUAL TELESCOPE.

The great difference between the photographic and visual

telescope is this: The eye with any telescope can see once for all what such a telescope will reveal. Prolonged observation will not add to the definition or the beauty of the picture. But the photographic telescope acts as an accumulator. Every tiny ray of light that falls upon the photographic plate is held there, and it is only necessary to prolong the exposure until rays are caught from stars of only the 20th magnitude. Unfortunately we are limited by the light of the sky in the length of our photographic exposures, and yet exposures have been made of 24 hours' duration, exposing the plate for eight hours each night and bringing the photographic images exactly superimposed upon those made the previous night. This can be readily done by the visual telescope which is always attached to the photographic equipment. In order that you may see what great difference there is in the detection of the minute and delicate structure of the universe, let us say of a nebulae, I show you a picture from a steel engraving of the great nebula in Orion which required the time of Professor Bond for all the spare time he could give to it during the evenings of three winters. You will see but little of the delicate detail of this beautiful nebulous body. And now I show you a picture of this great nebula in Orion photographed by my friend Mr. Ritchie at the Yerkes Observatory, on which I think the exposure was not over three or four hours. You will see a vast amount of detail here that is entirely missing in the picture as made by Professor Bond.

(Here a number of nebulae of similar type were thrown upon the screen to show the detail as brought out by photography.)

I have now the pleasure of showing you a spiral nebula which was taken by my friend Ritchie with a reflecting telescope, and which shows the wonderful structure of these spirals, from which Professors Moulton and Chamberlain have deduced a new theory of the formation of the stellar systems. Professor Keller, whom many of you knew, wrote me just before his last illness that he believed that the greatest discovery

he had ever made was that spiral nebula was the predominant form of the nebulous structures in the heavens, and he made the startling statement that he believed not less than 120,000 of these spiral nebulae were within the reach of the Crossley telescope of the Lick Observatory.

When we look at the heavens on the clearest night our eye can distinguish not more than about 3,000 individual stars

FIG. 4. Cluster of Stars in Saggitarius.

in the entire hemisphere of the sky. With a telescope of 12 in. aperture this number can be multiplied probably by 30. But the photographic telescope has revealed to us a multitude of stellar worlds such as we never dreamed of before it was invented. I show you a plate taken by Dr. Thome, of the Cordova University of a beautiful little cluster in Sagirtarius. Not a single star in this cluster is visible to the naked eye, but upon the plate I show you not less than 15,000 stars have been photographed, and I have seen a photographic plate made by my friend Dr. Gill, of the Cape of Good Hope, on which there were not less than 200,000 stars imaged; each one a burning sun like our own.

CUMULATIVE EFFECT OF PHOTOGRAPHY.

I now place upon the screen three plates as illustrative of the cumulative action of the photographic telescope. Here is a picture taken by Dr. Gill of the stars around Eta Argus with an exposure of 3 minutes 45 seconds. There are probably 100 stars on the plate. I show you a second picture exposed over three hours, and you will see upon the plate at least 1,000 stars and you will also notice a considerable nebulous condensation around the central stars. The next plate was exposed on three separate nights, the entire exposure being 24 hours. On this plate there are probably 20,000 stars and the nebula has become so prominent that it now extends more than half way over the entire field.

COMETS—SMALL PLANETS.

In photographing comets we have learned more about these erratic visitors to our solar system than ever had been previously known. I show you three pictures taken on three consecutive nights, in which you will see marvelous changes recorded in a comet when near its perihelion. The photograph has shown that these cometary bodies often throw off a part of themselves which in all probability is either dissipated into the ether of space or goes to make up the bodies of other and smaller comets.

In the search for the smaller planets whose orbits are between Mars and Jupiter the photographic telescope has revealed many of these minute bodies, which were not previously known to exist. Dr. Max Wolf with the 16 in. camera lens made for him has caught more than 100 of these little plane-

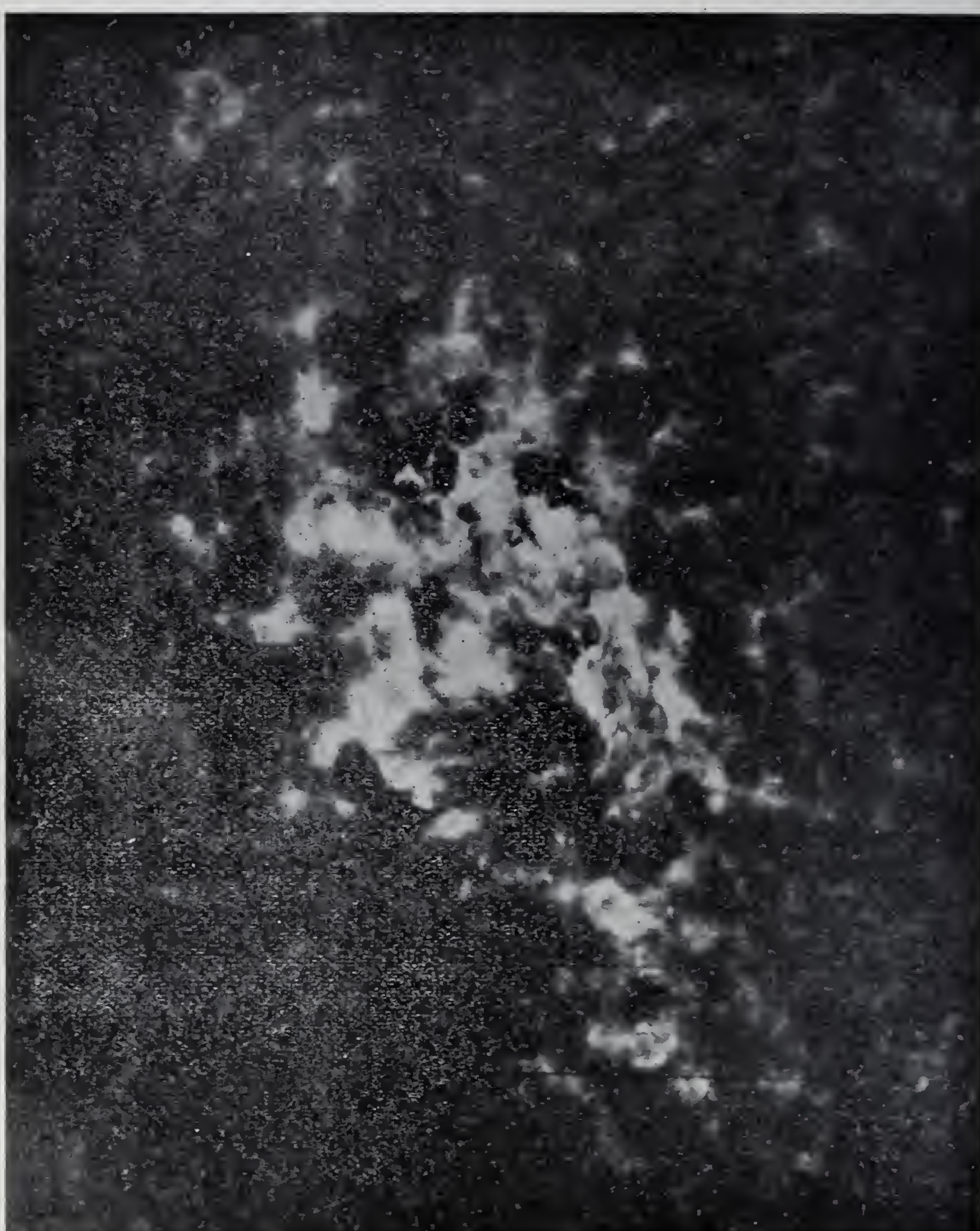


FIG. 5. Spectro Heliograph of the great Sun Spot of October, 1903.

FIG. 6. Solar flames of Hydrogen Gas extending from 40,000 to 70,000 miles above the Sun's surface.
Photo by Barnard, Eclipse of 1900.

tary bodies revolving between the orbits of Mars and Jupiter, all of which are new. To one of them he has given the name of Pittsburghia and to another Alleghenia, and every month he with his co-workers at the observatory at Heidelberg are adding from three to five of these new planetary bodies to the solar system.

PHOTOGRAPHING THE SUN.

Knowledge of our own sun has been marvelously increased by the aid of photography. With an instrument called the spectro-photo-heliograph we are enabled to dip our cameras right into the very midst of a solar storm and determine what is going on in any of the gases that are burning on the sun's surface. I show you a picture taken by such an instrument in October, 1903, which shows the distribution of the gaseous element calcium in a solar cyclone. And not only can this picture be taken right in the center of the sun, but the great solar flames that so frequently burst forth from these cyclones can be readily photographed at any time during their eruption near the edge or the limb of the sun. I show you a picture taken during the eclipse of 1900 with a very long focus lens, which shows these prominences with great beauty, one of the larger attaining a height of 70,000 miles. These photographs were heretofore deemed impossible except during a total solar eclipse, but by the aid of the spectograph and spectophoto heliograph not only can this but many other allied phenomena be photographed at any time the sun is shining.

PLANETARY PHOTOGRAPHY UNSATISFACTORY.

Planetary photography has so far been a failure. I know you have heard of photographs of Mars showing its canals, etc., but the picture I show you, made by my friend Barnard, of the Yerkes Observatory, with a special lens made for the purpose, gives but little detail and is very unsatisfactory indeed. The reason of this is easy to explain. The image of the planet Mars

FIG. 7. The Planet Saturn.

Fig. 8. Moon in her First Quarter.

in our 13 in. telescope at the Allegheny Observatory would not be as large as an ordinary pin head, and you can readily see that to magnify this to the extent demanded to bring out the

details that can be seen visually is almost an impossibility. I show you several photographs of the planetary bodies, but they are as yet far from what they should be, and it is really the only part of astronomical work that has not been satisfactorily accomplished by photography.

The moon has yielded marvelous pictures, some of which I show you upon the screen. The detail on its surface is beautifully delineated and some of the photographic studies of the moon have been enlarged to six feet in diameter. The pictures made at the Paris Observatory are on a scale of one meter to the moon's diameter, and marvelous are the details in these pictures of the lunar surface.

PHOTOGRAPHS WITH THE SPECTROSCOPE.

Photographs taken with the spectroscope are giving us a wonderfully comprehensive knowledge of the structure of the stellar worlds, their differences, their temperatures and their motions, and quite a number of observatories, among them our own, are engaged at the present time in determining the motions of the stars by this wonderful method. It may be interesting to know that astronomers have now practically determined the motion of our own system in space, not only in direction but in velocity. A long series of observations indicate that we are traveling toward the constellation of Hercules at the rate of twelve and a half miles per second, or 1,080,000 miles per day.

TEMPORARY STARS.

And finally the photograph has shown us that stars that frequently appear in the heavens which we have chosen to call temporary stars, probably constitute one of the last phases in the life history of the universe to us mortals. I throw upon the screen a picture of the brilliant star that burst forth in February, 1901, in the constellation of Perseus. In all probability the brilliance of this star was caused by the collision of two stellar worlds meeting in space. The spectro-

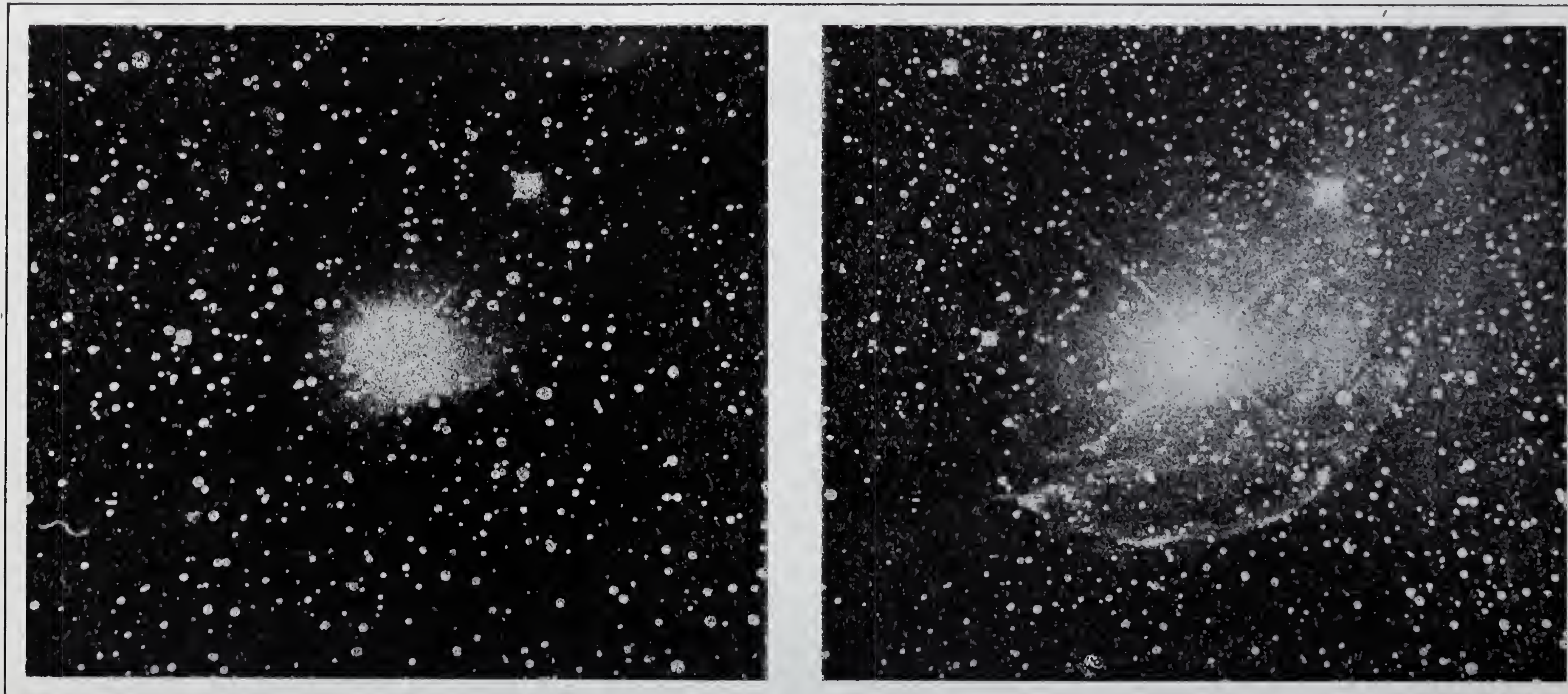


FIG. 9. New Star in Perseus, showing the marvelous change in about two months.
One photo taken in September, the other in November, 1901.

scope showed that there was a great outburst of hydrogen gas. . The photograph shows a marvelous difference between the star as, it was shown in September and in November of the same year. It will be noted that the nebulous mass thrown out from these stellar worlds is beautifully shown upon the photograph. It is far beyond the reach of the visual telescope. Tonight the astronomer can see but a tiny point of light where this great start burst forth in February, 1901, and it evidently tells us a story of the destruction of worlds, or rather their rehabilitation in the nebulous form, to go through the evolution of star making again.

Such in brief is the story of what a piece of glass, properly shaped by the hand of the skilled optician and used by the astronomer, has brought to the knowledge of us mortals. It is a story replete with interest from beginning to end, and yet I have told you but a few of the beautiful facts associated with this charming subject.

Before the Structural Section, January 7th, 1908.
Chairman E. W. Pittman
In the Chair.

NEW FORMS OF STEEL FOR NEW USES.

By R. B. Woodworth,*
(Non-Member).

It is usually supposed that statistics are of value only to those who take delight in abstruse mathematical calculations without regard to any material use or benefit derived therefrom, and that ordinarily a practical man engaged in the useful pursuit of lucrative employment has little or no interest in them, and yet beyond question, the statistics of an industry constitute an invaluable record of that industry's course and development, and an intelligent analysis of statistics may be of great importance and interest, and may result in the ascertainment of historical facts of value.

Let us take, for example, the production of steel plates and sheets, exclusive of nail plates, in the United States during the period covered by ascertainable records:

	Gross Tons
1887	603,355
1888	609,327
1889	716,496
1890	809,981
1891	678,927
1892	751,460
1893	674,345
1894	682,900
1895	991,459
1896	965,776
1897	1,207,286
1898	1,448,301
1899	1,903,505
1900	1,794,528
1901	2,254,425
1902	2,665,409
1903	2,599,665
1904	2,421,398
1905 (plates 2,041,206; sheets, 1,491,024)	3,532,230
1906 (plates)	2,010,347
1907 (plates, estimated)	2,025,962

Up to 1904 the statistics of the American Iron & Steel Association did not distinguish between plates and sheets; in 1905 there were produced a total of 3,532,230 gross tons of plates and sheets composed of 2,041,206 gross tons plates and 1,491,024

* Engineer, with Carnegie Steel Company.

gross tons sheets. In 1906 and 1907 the production of plates alone amounted to 2,010,347 and 2,025,962 gross tons respectively.

Now the statistics of the production of steel plates is in a measure an index to the development of certain classes of construction distinctive of the closing years of the nineteenth century and the inception of the twentieth. Steel as a material for shipbuilding construction was first introduced under modern methods of manufacture during the period from 1870 to 1875, but the first all-steel merchant vessel seems to have been the Cunard liner "Servia," built in 1881, and the first all-steel battleship seems to have been the "Benbow," constructed by the English government in 1885. In the year 1900, however, 93.21% of all the vessels of 100-ton register and over, whether on lake or ocean service, were constructed of steel, and the steady growth of plate production shown in our list marks the gradual development of the shipbuilding industry. This development continued to be gradual until about 1896, about which time the first steel railway car was built by the Keystone Bridge Works. Since that date the rapid increase in plate production reflects the rapid development in the manufacture of steel cars. About 1898 the Schultz Bridge Company, at McKees Rocks, built the first steel barge for river transportation, and the increased use of steel barges on our own rivers has added its quota to the increased production of steel plates.

The production of steel shapes, meaning by that beams, beam girders, zees, tees, channels, angles, etc., is an index to the development of the steel bridge and especially of the steel building. In 1884 the first 15-inch steel beams were rolled at Upper Union Mills. They were followed by the rolling of 20-inch beams on the 33-inch mill, Homestead Steel Works, January 3, 1888; 24-inch beams on the 33-inch mill, Homestead Steel Works, June 19, 1889, and 18-inch beams on the 35-inch mill, Homestead Steel Works, February 3, 1897. The rolling of these sized beams has made possible and economical the skeleton steel building, and the production of shapes has grown in accordance with the growth of the modern office building in

the principal cities of the United States. The production is as follows:

	Gross Tons		Gross Tons
1892	453,957	1900	815,161
1893	387,307	1901	1,013,150
1894	360,305	1902	1,300,326
1895	517,920	1903	1,095,813
1896	495,571	1904	949,146
1897	583,790	1905	1,660,519
1898	702,197	1906	1,707,636
1899	850,376	1907 (estimated)	1,627,642

It may be said, however, that the skeleton steel building is a vital necessity within large commercial centres, and that the commercial expansion of the United States would of itself have compelled the erection of these buildings regardless of the use of steel in their construction. The point now made is that the use of steel has made economical their construction, and while causes act and interact among themselves, yet beyond question a low-priced economical material is the essential condition of building construction. When steel was not the convenient material it is, other forms of construction may have taken its place, but as matters stand today, steel is the only material known to the engineering profession which is absolutely homogeneous in all particulars, of unquestioned strength and reliability, easy to fabricate and erect, convenient and satisfactory in all respects.

Besides its unquestioned economy, there are two considerations which have led to the large use of steel as the ideal building construction. The first of these which we will mention is its fireproof character. This is not the principal reason, but beyond question it is a very important one.

George E. Walsh has spoken of our country as "Combustible America," and a consideration of the facts in the case prove the correctness of that designation. Our annual fire bill has been steadily growing as our population increases. In 1905, for example, building operations throughout the country represented a total investment of $525,000,000, and in 1906,

the high-water mark in the nation's history, $700,000,-000. In 1904 our fire losses alone aggregated $229,198,050. In 1906 the losses in the United States and Canada by fire were $536,860,400. Of this last sum San Francisco was responsible for $350,000,000, including buildings and contents. We speak of the spectacular burning of Rome in the days of Nero, and the great conflagration of ancient London, but these are not to be mentioned in the same breath with the fires of Chicago, Baltimore and San Francisco. The destruction of property by fire is only a part of the losses entailed on our country.

Our people have borne their fire losses and have rebuilt the same kind of structures until it has become fully realized that the part of wisdom lies in the construction of buildings which are in themselves fireproof, and that wiser economy is found in the construction of better buildings than in decreased first cost. Consequently while the number of fireproof buildings is still really small, even in our largest cities, yet beyond question the requirements of fireproof construction have been and will continue to be large factors in the extension of the use of steel. The evolution in building which has not yet reached its culmination, dates back to the first introduction of rolled I-beams of iron in France and Belgium in 1854, but the famous Chicago fire showed the unreliability of unprotected iron beams in a hot fire. Unprotected steel is a better fire-resisting material than unprotected iron, but the ideal modern building is a skeleton structure of steel fully protected by refractory materials, which, by reason of being once burnt, are in a position to resist successfully, as they have done in numerous instances, the hottest temperature an office or warehouse building can develop.

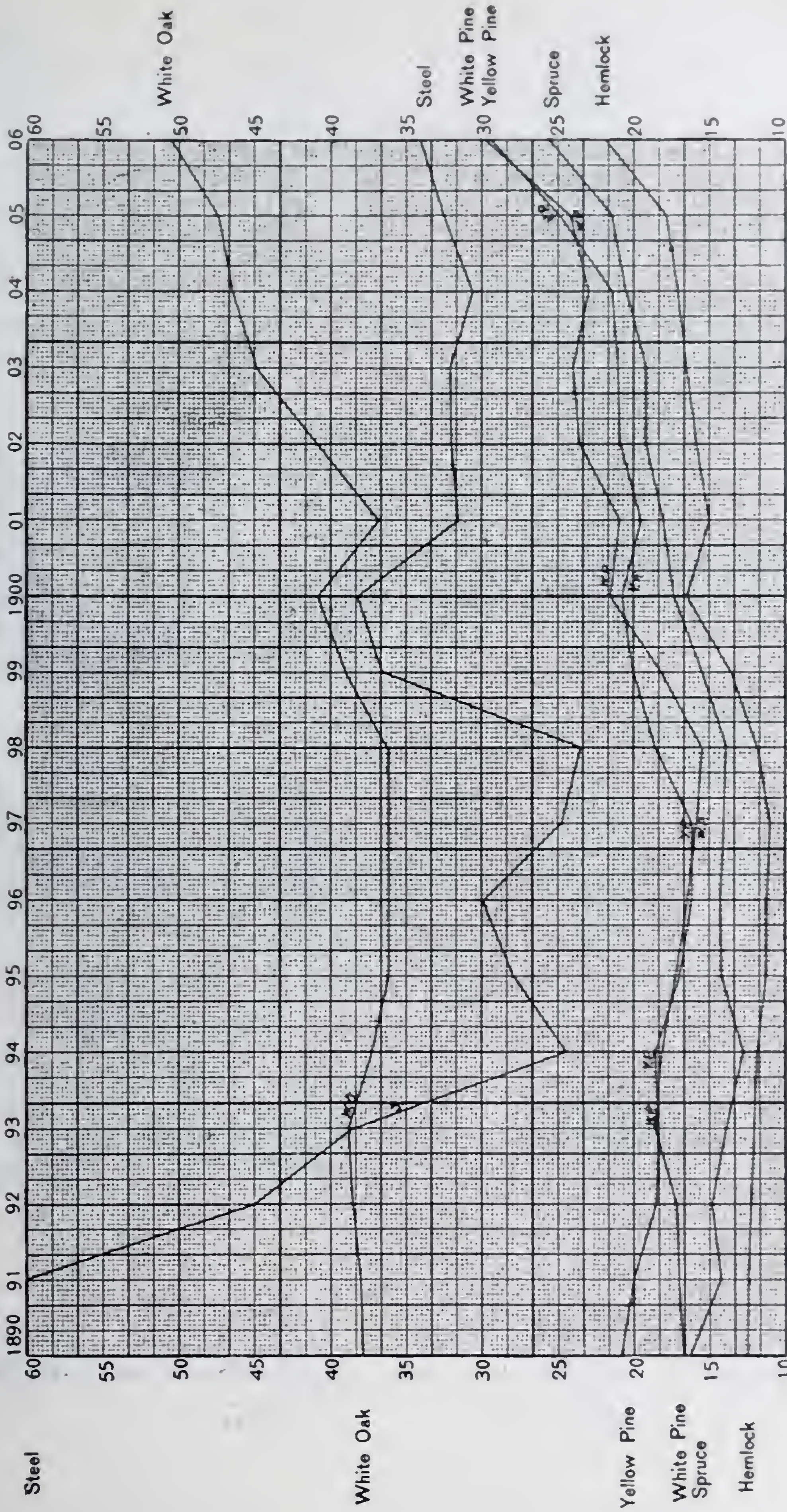
The chief factor, however, which has occasioned great extension in the use of steel bridges and buildings has been the rapid increase in the cost of timber, as well as the great decrease in the quality of the timber which actually comes on the market, and in this connection the annexed table and drawing Figure 1, showing the course of wholesale prices prepared from statistics furnished by the Bureau of Commerce and

Labor, demonstrates very plainly that the price for lumber per thousand feet is gradually approaching the price of steel per ton, and that if conditions now in force continue, the difference between steel and wood will be quickly diminished.

COURSE OF WHOLESALE PRICES.

	Hemlock.	White Oak.	White Pine.	Yellow Pine.	Spruce.	Steel.
1890	12.58	37.88	16.79	20.75	16.29	60.00
1891	12.46	38.00	17.00	19.96	14.22	60.00
1892	12.29	38.46	17.15	18.50	14.85	45.00
1893	12.00	38.75	18.62	18.50	13.77	38.60
1894	11.71	37.25	18.17	18.50	12.71	24.65
1895	11.15	36.25	17.25	16.92	14.25	28.00
1896	11.17	36.25	16.50	16.42	14.25	29.90
1897	11.00	36.25	15.83	16.44	14.00	24.75
1898	11.75	36.25	15.50	18.62	13.75	23.45
1899	13.52	38.96	18.20	20.04	15.40	36.60
1900	16.50	40.83	21.50	20.71	17.38	38.20
1901	15.00	36.77	20.88	19.67	18.00	31.55
1902	15.83	40.88	23.50	21.00	19.25	32.00
1903	16.79	44.83	24.00	21.00	19.19	32.00
1904	17.00	46.50	23.00	21.42	20.50	30.60
1905	17.88	47.33	24.17	24.92	21.42	32.60
1906	21.90	50.42	29.75	29.33	25.54	34.00

The price of steel beams and channels is given f. o. b. cars, Pittsburg, in dollars per ton of 2000 lbs. Prices for lumber are given in dollars per thousand feet board measure. Prices for hemlock are based on 2x4 pieces 12 to 14 f t.long, Pennsylvania stock, f. o. b. New York. Prices of white oak are for 1x6 boards, same place. Prices of white pine are for No. 2 barn grade, 1x10 rough, f. o. b. cars, Buffalo. Yellow pine prices are for 1 in. long leaf boards, f. o. b. cars, New York, and spruce 6 ft. to 9 ft. cargoes, New York City. It is to be noted that since 1897, a year of great industrial depression, the price of timber of the grades used in building has practically doubled and while the price of steel has been subject to great fluctuations and stands today, due to improvements in manufacture; at relatively low figures, the price of lumber has steadily increased.



COURSE OF WHOLESALE PRICES OF TIMBER AND STEEL

Steel in Dollars per Net Ton   Timber in Dollars per Thousand Feet

FIG. 1.

Among other things, this chart shows very plainly that the prices of timber per thousand feet and the price of steel per net ton have approached very closely to each other; that the question of comparative cost is not today the feature it was

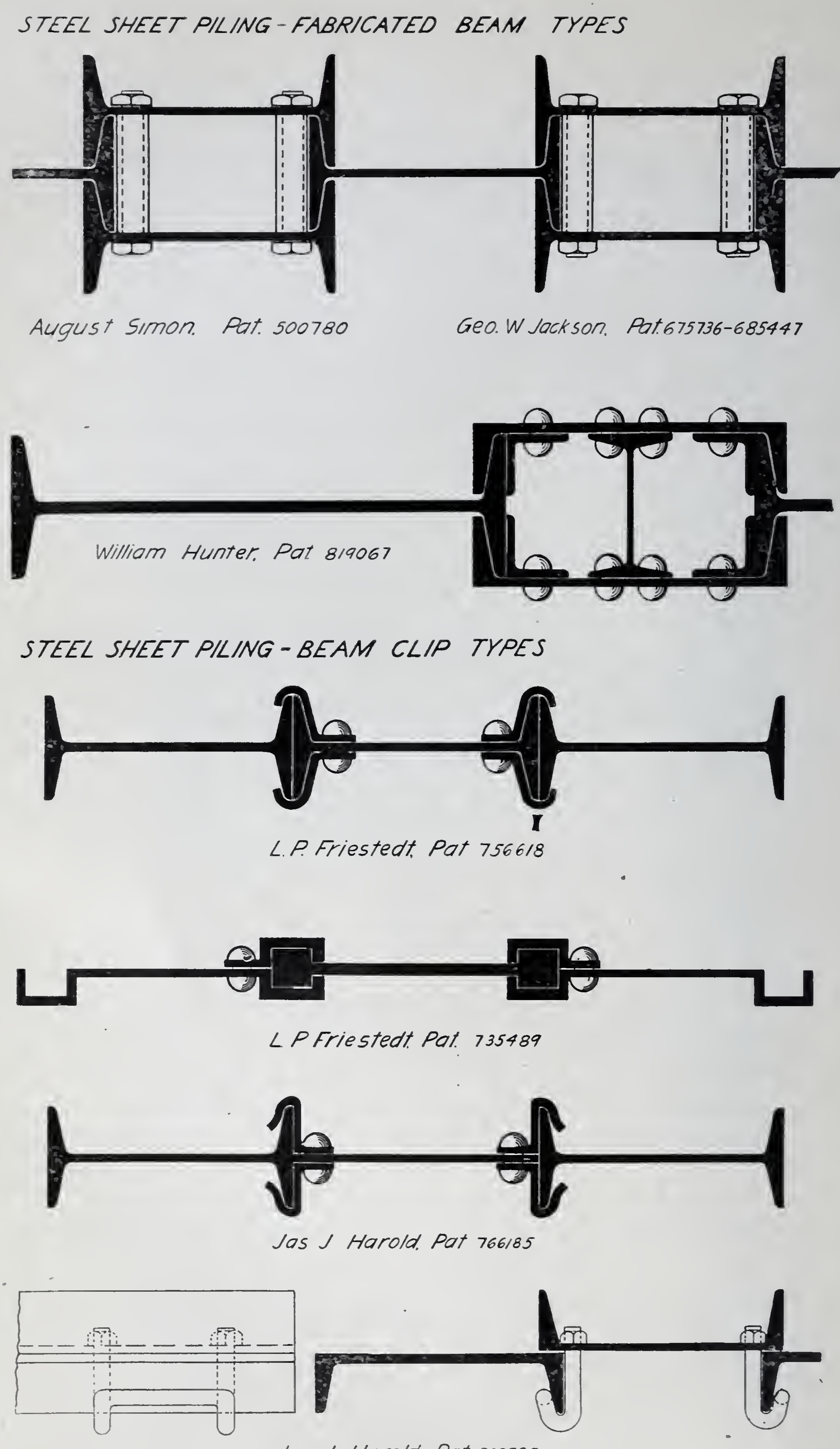

STEEL SHEET PILING - FABRICATED BEAM TYPES
August Simon. Pat. 500780
Geo. W Jackson. Pat. 675736-685447
William Hunter. Pat 819067
STEEL SHEET PILING - BEAM CLIP TYPES
L. P. Friestedt. Pat 756618
L P Friestedt Pat. 735489
Jas J Harold. Pat 766185
Jas J Harold. Pat 808985

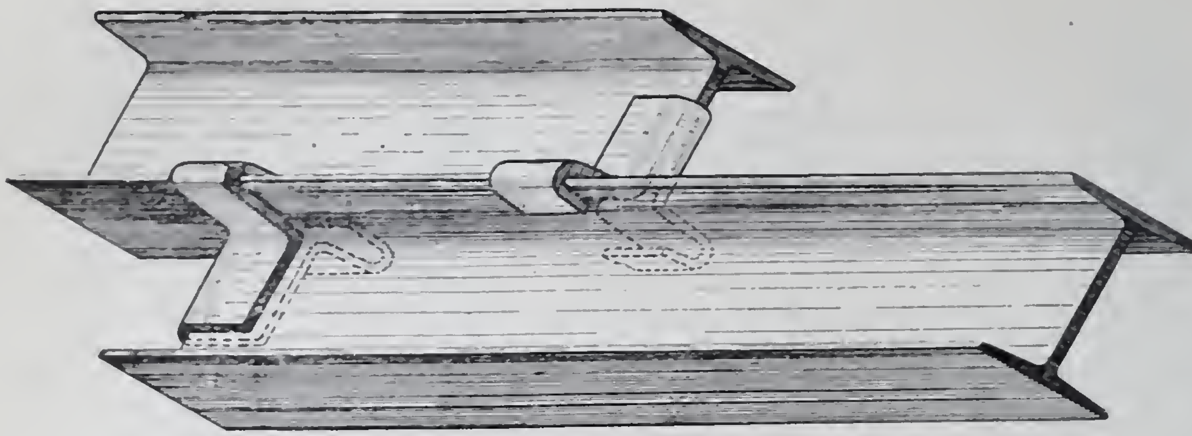
FIG. 2.

ten years ago, and that the comparative first cost of wood is not very much of an item when compared with the much longer life of steel, its much more satisfactory character and its convenience in manufacture and erection; and beyond doubt the development of the immediate future lies in the rapidly increasing substitution of steel for wood in all classes of ordinary building construction. Of course, in the modern building, some place will be taken by reinforced concrete, which is a material that offers numerous advantages for those places in construction for which it is peculiarly suitable. It cannot, however, take the place of steel, and the building laws of our best cities have begun to reflect the prevailing opinion of the engineering profession to the effect that reinforced concrete must be used under conditions of the most careful manufacture and inspection, and that even when so used, its use on high buildings must necessarily be restricted. There is no restriction to the use of steel.

It would be very interesting to touch upon quite a number of the uses of steel, which distinctly mark the beginning of the twentieth century. Iron has given place to soft steel in the manufacture of all kinds of agricultural shapes and machinery. Special forms of steel are used in the manufacture of turbine plates for the construction of the turbine, so prominent in transmission line construction. Steel wheels, whether cast or forged, or steel tired, are rapidly taking the place of the ordinary iron castings, and we hear no more of the compressed paper wheel, which, it will be recalled, was seriously advocated some years ago. Our heaviest and best trains, composed of steel cars and coaches, are carried safely over roadbeds constructed of steel ties. The steel tie has not yet supplanted wood, but beyond question will form the ideal roadbed of the future.

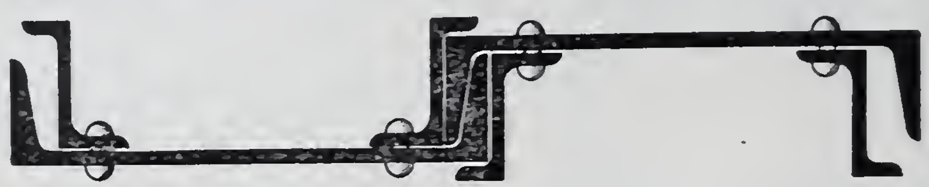
The production of structural shapes in this country, as has been stated, reflects accurately the expansion of steel construction in buildings and bridges, or the increasing use of steel in that class of construction which deals with the superstructure. It is confidently believed that the application of steel

STEEL SHEET PILING - BEAM CLIP TYPES

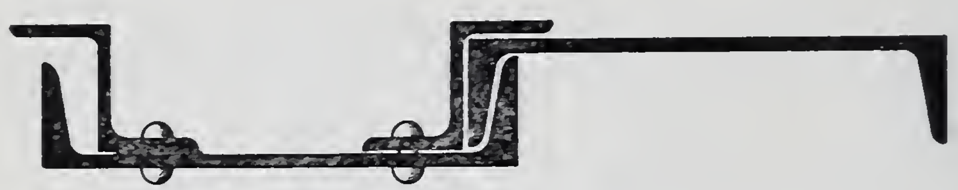


Geo E Nye

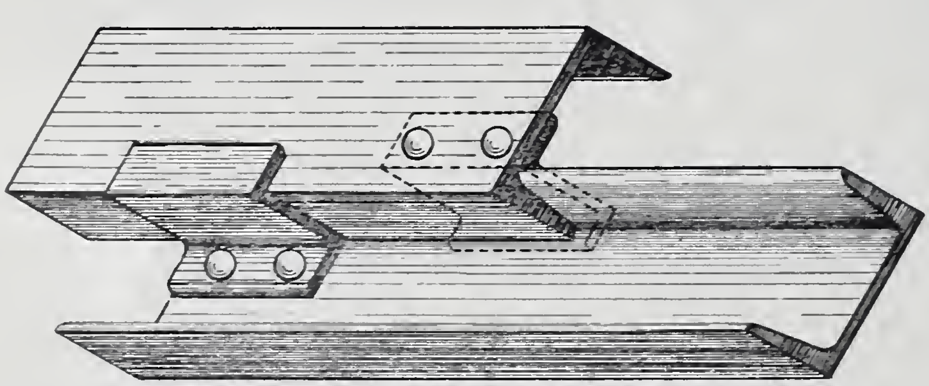
STEEL SHEET PILING - INTERLOCKING CHANNEL BAR TYPES



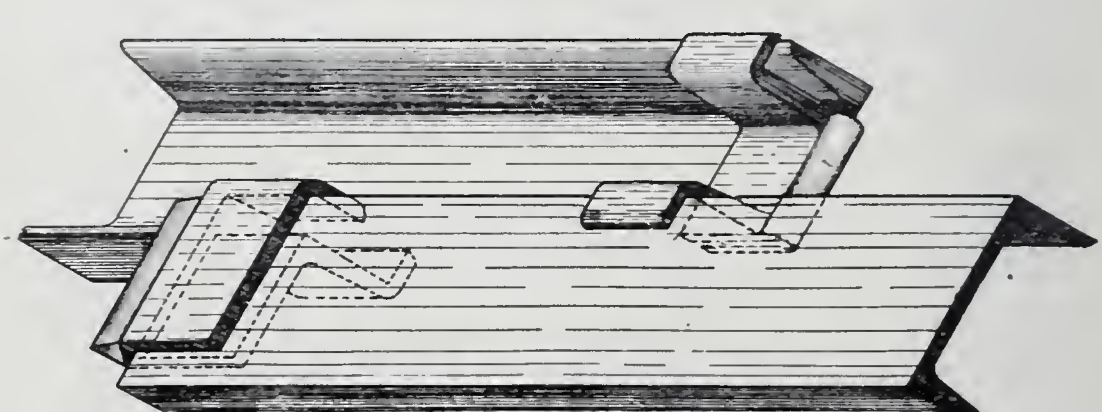
L P Friestedt Pat 707837



L P Friestedt Pat 707837



A A Friestedt



Geo E Nye, Pat. 860053

FIG. 3.

for use in the construction of foundations, coffer-dams, etc., will play a large part in the shape and plate production of the future. We have to speak, therefore, of modern methods of substructure construction, which offers large place for the substitution of steel for wood.

FABRICATED BEAM TYPE.

Round piles of cast iron seem to have been in use as early as 1822, but the invention and application of forms of steel sheet piling has fallen chiefly within the present twentieth century. These forms have varied as the inventors were numerous, and it is difficult to classify satisfactorily all the various types of steel sheet piling which are presented in the documents which have passed through the Patent Office covering this class of construction. There are, however, certain outstanding types which will be mentioned. First, the fabricated beam type. This type consists in the main of two standard beams or channels connected together by bolts and separators to form what might be called a box pile, the boxes being connected together in a straight line by standards beams or channels, the flanges of the single beams forming this connection interlocking with the flanges of the beams or channels forming the box. This type of construction was first covered by letters patent 500,780, granted on July 4th, 1893, to August Simon, of Gnadau, Germany, and the basal ideas of August Simon reappeared in the improvements made thereon in patents 675,736, of June 4th, 1901, and 685,447, granted October 29th, 1901, to Geo. W. Jackson, and it is to be noted that the first steel sheet piling used in the United States and driven in November, 1901, at Randolph Street Bridge, Chicago, Illinois, was of this type, which affords large possibilities in heavy submarine construction, but at the same time is deficient in its ability to furnish light-weight sections for ordinary cofferdam and sewer construction. The driving of the Jackson piling demonstrated the necessity of some provision to make the piling water-tight, and Jackson and Hogan patent 758,656, of May 3, 1904, covers

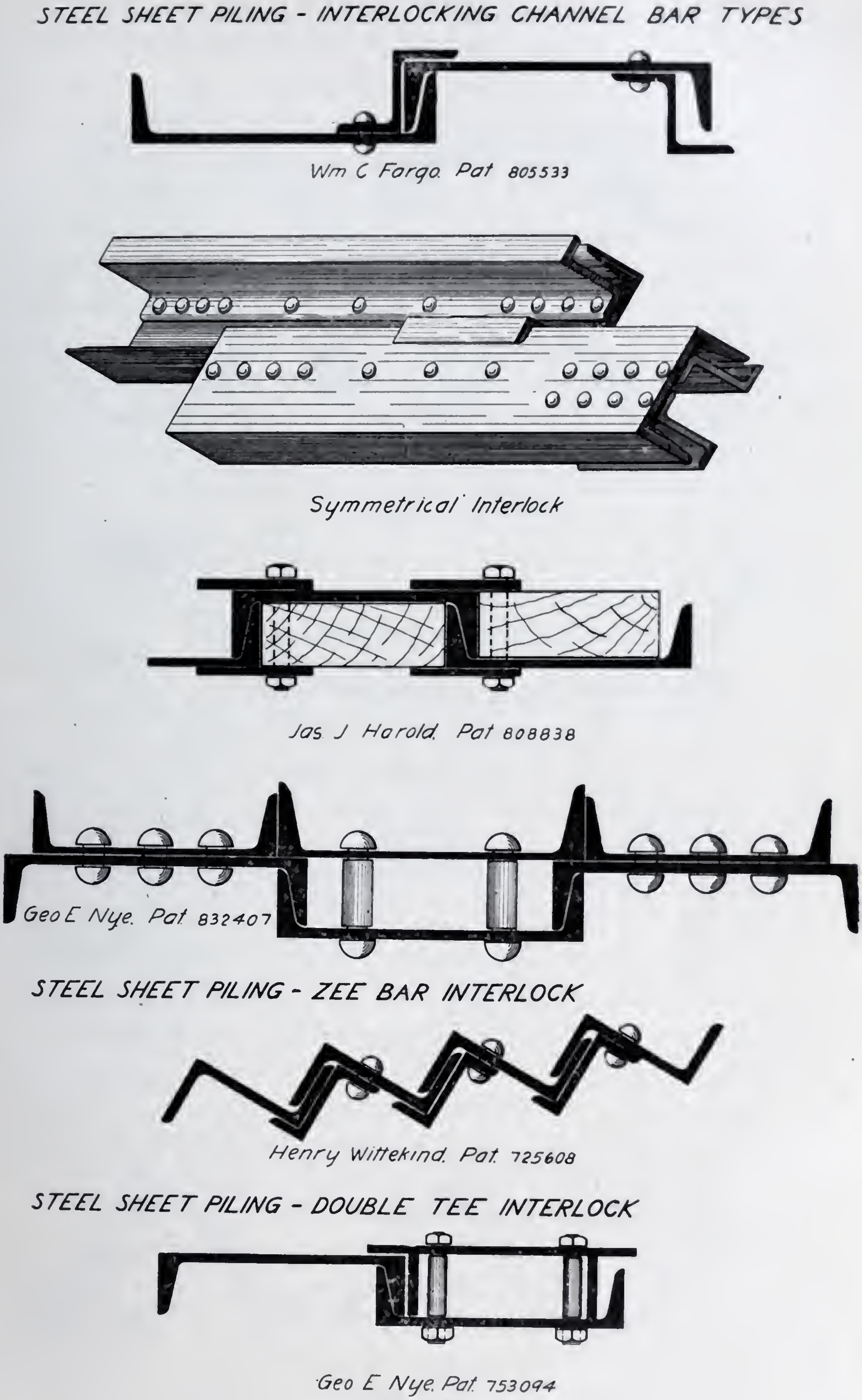
this feature of the fabricated beam type steel sheet piling. The further development of this type of piling is to be found in the ideas of Wm. Hunter, of Kincardine, Ontario, as recorded in patent 819,067, which consists essentially of a series of steel columns built up of beams and channels and connected together by heavy weight I-beams, which would make a form of construction that would be extremely difficult to drive and about four or five times as heavy as there is any need for, but which after it has reached its final position in the construction, would have the strength of Gibraltar.

BEAM CLIP TYPE.

The excessive weight of the fabricated type of beam piling led inventors to consider the use of beams aligned successively with the top flange of the one against the bottom flange of the other, which I will call the beam clip type. This is represented in patent 756,618 granted to L. P. Friestedt, of Chicago, on April 5, 1904, in which regular structural beams are used to form an interlocked wall. The weight of this section, however, caused Mr. Friestedt to turn his attention to a lighter form of construction based on the same idea. This is covered by patent 735,489, dated August 4, 1903, in which the place of beams has been taken by sections either round or square headed and similar to the bull-head rails in use on the railways of England. Mr. Friestedt's original ideas have proven fruitful in stimulating others to action, and Jas. J. Harold, of Jersey City, N. J., has taken out patents 766,185 of August 2, 1904, 807,378 of December 12, 1905, and 820,970 of May 22, 1906, in all of which the same idea occurs of connecting together standard beams assembled edgewise by clips which may be riveted either to beams themselves, or to a plate (Figure 3). The latest development in the idea of connecting standard beams by clips, either full length or of short pieces, appears in the latest patents taken out by Geo. E. Nye, of Chicago, Ills.

FRIESTEDT INTERLOCKING CHANNEL BAR PILING.

The beam clip type of piling, however, in spite of its simplicity and strength, due to its large radius of gyration, suffers


STEEL SHEET PILING - INTERLOCKING CHANNEL BAR TYPES
Wm C Fargo. Pat 805533
Symmetrical Interlock
Jas. J Harold. Pat 808838
Geo E Nye. Pat 832407
STEEL SHEET PILING - ZEE BAR INTERLOCK
Henry Wittekind. Pat 725608
STEEL SHEET PILING - DOUBLE TEE INTERLOCK
Geo E Nye. Pat 753094
FIG. 4.

from the same criticism already made on the use of beams in piling construction, namely, that due to the weight being beyond absolutely necessary requirements. It is this consideration which has called forth interlocking channel bar piling, which appears in different forms, but all of which are due in the ultimate analysis to the inventive genius of Mr. L. P. Friestedt, of Chicago, and the success of which in a large measure has made steel sheet piling one of the indispensable factors of substructure construction. Mr. Friestedt's basal patent is No. 707,837, granted August 26, 1902, and is so broad that it covers any combination of channel beams joined edgewise and having back and face sides thereto positioned alternately with reference to each other and presenting a wall structure of single thickness at all points, and also the combination of zee bars as applied to such channels to form an interlock. The broadness of this basal patent has been overlooked by some of Mr. Friestedt's competitors and there is being advertised extensively a type of piling which beyond question lays itself liable to serious infringement proceedings. It may be stated in a general way that it is hardly possible for a new inventor to design a form of steel piling which will not constitute an infringement on the patents already issued.

Patent 730,755 of June 9, 1903; 733,713 of July 14, 1903, 733,314 of July 21, 1903, and 834,051 of October 23, 1906, cover extensions and applications of Mr. Friestedt's original basal patent, and present modifications covering constructions adaptable to corners, etc. The first of the Friestedt interlocking channel bar piling was driven in October, 1902, in the mine shaft of the Johnson City & Big Muddy Coal & Mining Company, at Johnson City, Ills., and its increasing use by the engineering and contracting profession has demonstrated the correctness of the ideas on which it was based.

In the endeavor to get away from the weight due to use of zees extending the full length of the channels and forming a continuous interlock, the idea has arisen that it might be possible to use short pieces. This has given rise to the *clip interlock*, which appears in the first instance in patents 734,843 of

STEEL SHEET PILING - INTERLOCKING TROUGH PLATE TYPES

Frank Kneas, Pat 744361

Walter L Cowles & Jas. N Hatch, Pat 751469

Julius R. Wemlinger. Pat. 801946

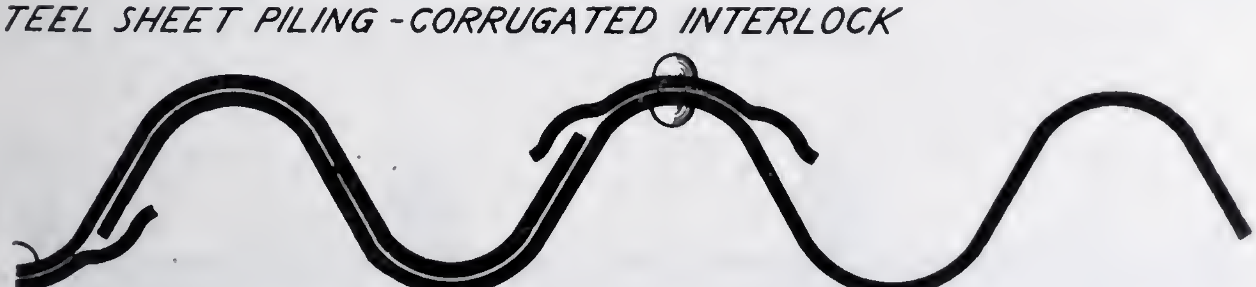
STEEL SHEET PILING - BOX INTERLOCK

Geo. W. Jackson. Pat 697943

STEEL SHEET PILING - SCROLL INTERLOCK

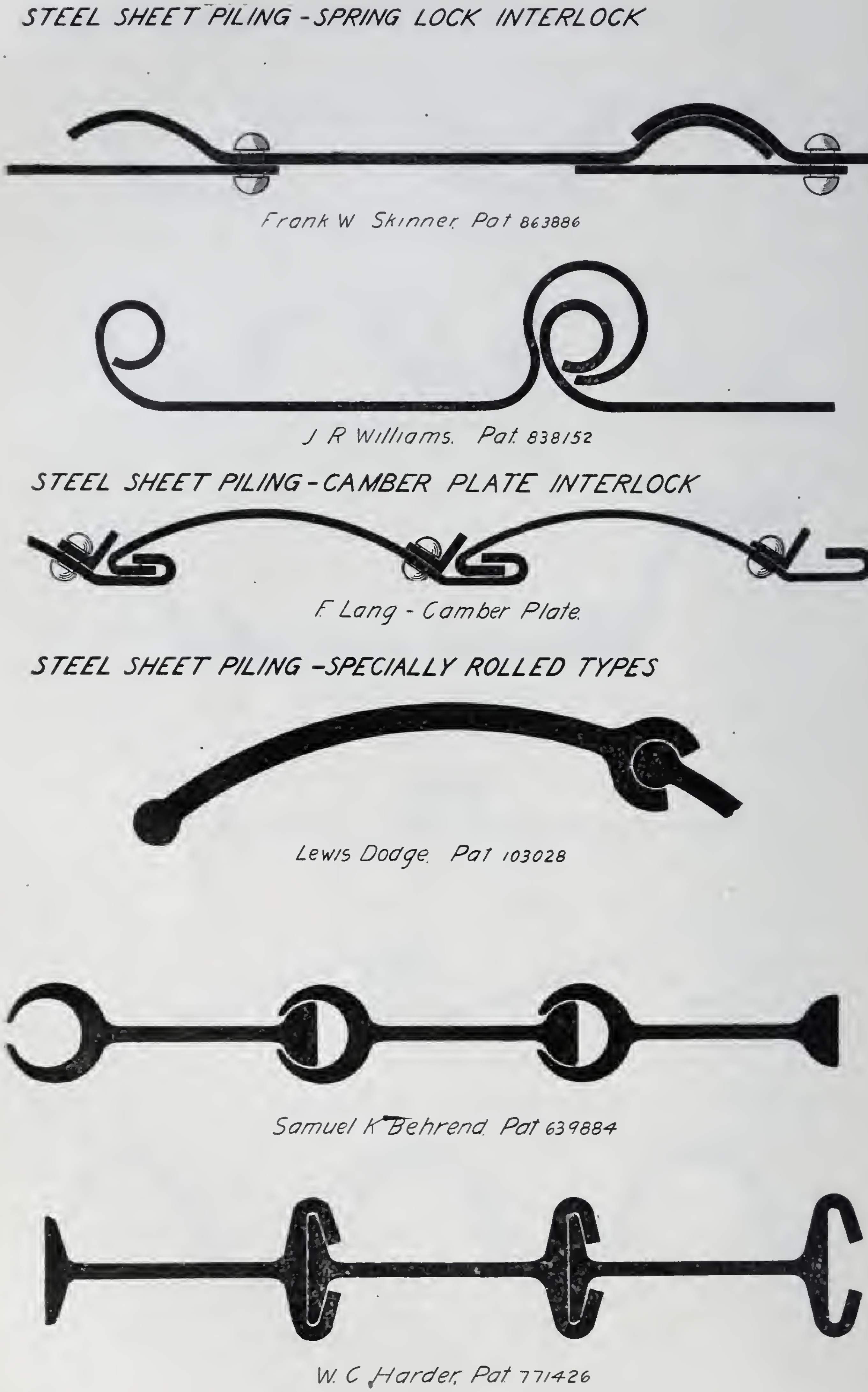
R.H. Stevens, Pat 824513

STEEL SHEET PILING - CORRUGATED INTERLOCK



Lester G. Gifford & R.V Sage Pat 766132

FIG. 5.


STEEL SHEET PILING - SPRING LOCK INTERLOCK
Frank W Skinner. Pat 863886
J R Williams. Pat. 838152
STEEL SHEET PILING - CAMBER PLATE INTERLOCK
F. Lang - Camber Plate.
STEEL SHEET PILING - SPECIALLY ROLLED TYPES
Lewis Dodge. Pat 103028
Samuel K Behrend. Pat 639884
W. C Harder. Pat 771426
FIG. 6.

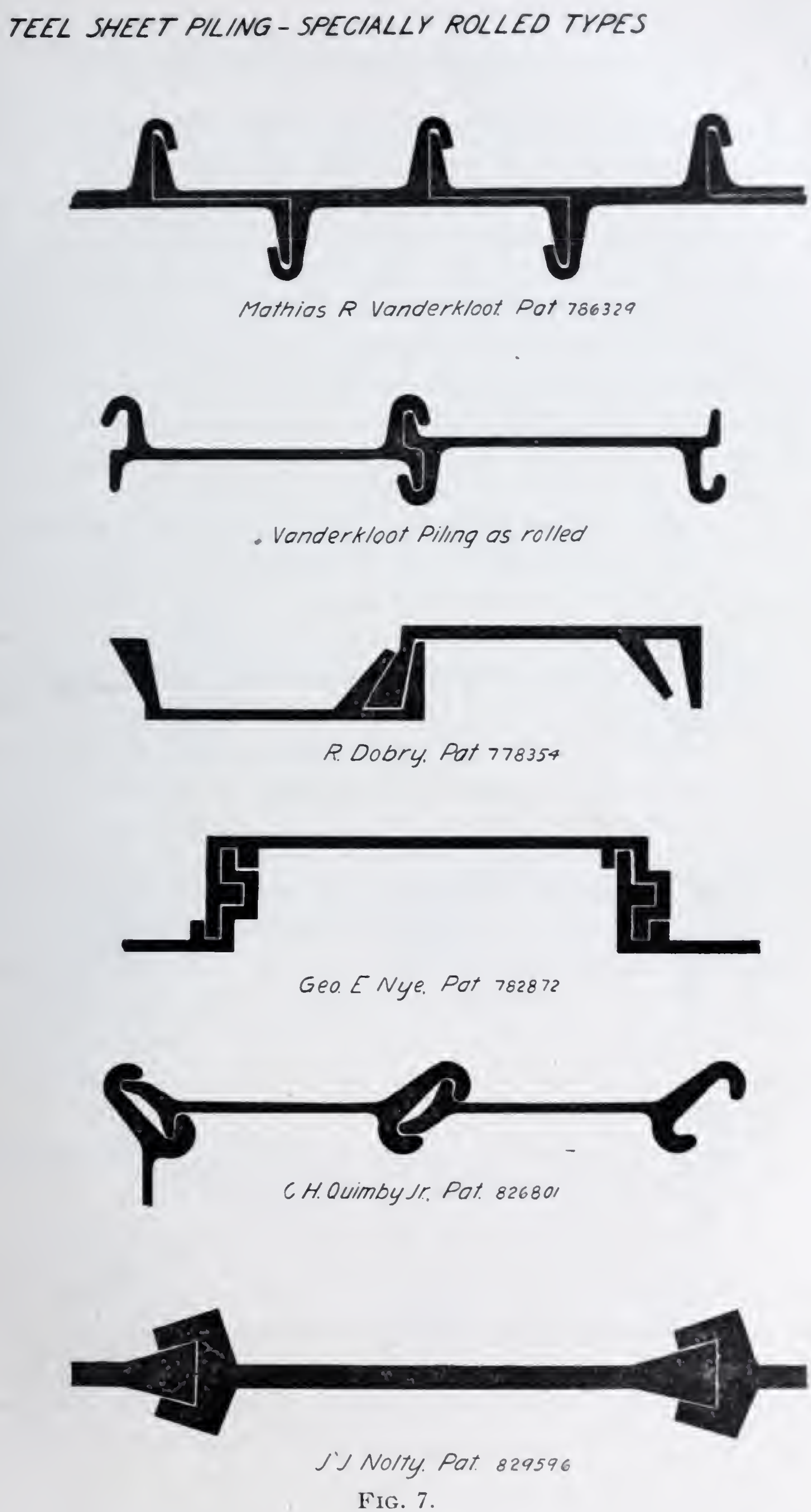

TEEL SHEET PILING - SPECIALLY ROLLED TYPES
Mathias R Vanderkloot Pat 786329
Vanderkloot Piling as rolled
R. Dobry. Pat 778354
Geo. E Nye. Pat 782872
C H. Quimby Jr. Pat. 826801
J J Nolty. Pat 829596

FIG. 7.

July 28, 1903, and 739,072 of September 15, 1903, granted to L. P. Friestedt, and covering frictional pieces to wedge the steel piling members closely together, and at the same time to do away with the excess weight. This idea had hardly passed into history before it was followed by patent 808,985 granted to Jas. J. Harold, of Jersey City, on January 2, 1906, in which a clip interlock is formed by double U-bolt connecting adjoining channels or beams together. Mr. A. A. Friestedt has patented a clip successor to the full length interlock, his idea being to use short length zees simply to guide the channels in driving and to depend upon the frictional resistance of the channels themselves and earth or water pressure to form a continuous interlock. Mr. A. A. Friestedt's ideas have been reflected in patent 860,053 of July 16, 1907, and 871,177 of November 19, 1907, granted to Geo. E. Nye, of Chicago, in which the clips are formed not of rolled zee bars, but of steel castings approximating the zee bar shape. Experimental tests with the clip form of steel piling have shown that while it may be admirably suited to light, easy driving in shallow soils, it cannot be depended upon for heavy work through quicksands, boulders or other closely compacted material, for the reason that inasmuch as the channels are fastened together only at the top and bottom, the driving of the piling to a refusal will necessarily tend to cause the channels to buckle about their middle and open out, thus destroying any effective interlock, and resulting, in submarine work, in excessive leakage which cannot be stopped except by expensive means, which produces undue delay in operation.

There is an advantage in the clip interlock in having zees on each piece to hold material in exact alignment.

Mr. Wm. G. Fargo, of Jackson, Mich., had occasion to use in the construction of the dam for the Grand Rapids-Muskegon Power Company quite a quantity of Friestedt interlocking channel bar piling under difficult conditions of driving. He discovered very shortly the inherent weakness of the Friestedt interlocking channel bar piling, which consists in the fact that the plain channel composing the alternate section has but a

small radius of gyration and shows a tendency to buckle under heavy driving. To obviate this disadvantage, Mr. Fargo had fabricated by the Friestedt Company a quantity of piling which differed from that covered by the Friestedt basal patent in having a single zee bar riveted to each piece instead of two zees riveted to alternate sections. By this means he succeeded in making each piece of the same strength and found that the most difficult driving could be satisfactorily accomplished. His ideas have been covered by patent 805,533 dated November 28, 1905.

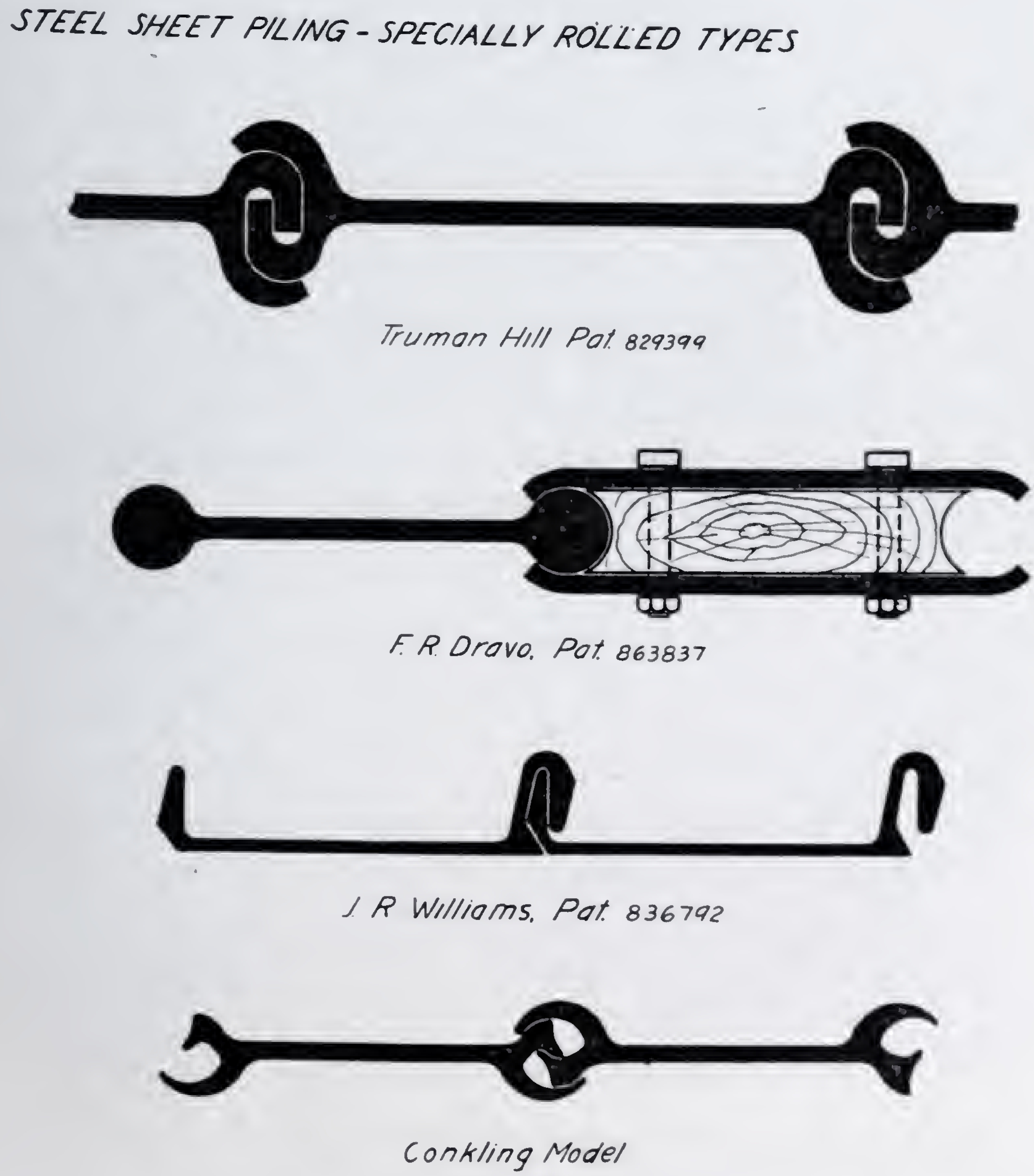


FIG. 8.

SYMMETRICAL INTERLOCK.

Mr. Fargo in his patent claims only an improvement on the Friestedt form of steel piling. Mr. Fargo's own piling, however, is subject to the disadvantage that in driving there is nothing to hold alternate sections in alignment except the pressure of the material and the friction in the pile-driver leads. Consequently there has been devised a further improvement called the symmetrical interlock, which consists in riveting a single zee bar full length on each section at one edge, with a short piece at the other edge at the top only of each member, the function of the short clip piece being only to hold the material in alignment, and to distribute the blow of the pile-driver more uniformly over the section than is done in the Fargo type.

The success of Friestedt interlocking channel bar piling has incited Mr. Jas. J. Harold to work up a wooden composite type of piling based on the use of standard channels in which the zee bars are omitted and the channels held together by short bars, overlapping the interlocking flanges and bolted to wooden timbers, making a solid steel and wood wall. This form of composite piling is covered by patents 808,838 of January 2, 1906, and 820,304 of March 8, 1906.

INTERLOCKING DOUBLE CHANNEL BAR.

Mr. Geo. E. Nye has exercised his inventive genius further on interlocking channel bar piling with the result that in patents 832,407 of October 2, 1906, 850,043 and 850,044 of April 9, 1907, he has developed what might be called interlocking double channel bar piling. This form might be successful under heavy driving conditions but is too heavy for ordinary use and patents 850,043 and 850,044 require special rolled shapes for their manufacture, thus entailing additional expense over the other forms.

INTERLOCKING ZEE BAR.

The success of the interlocking channel bar piling called forth interlocking zee bar piling, represented in patent 725,608

FIG. 9. Coffer Dam for concrete river wall at National Tube Co.'s Pennsylvania Department, Pittsburgh.

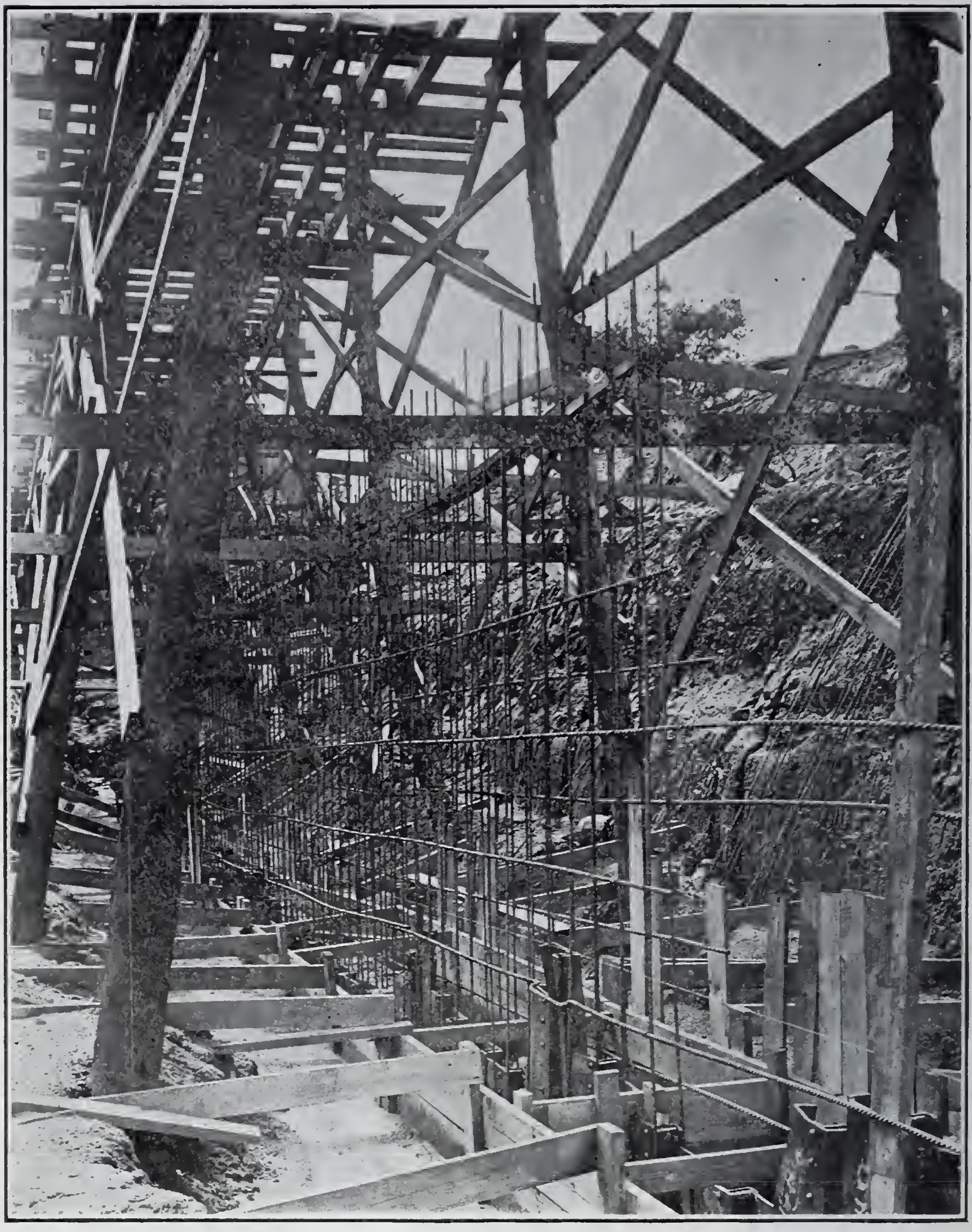


FIG. 10. Dam for Berrien Springs Power Co., Berrien Springs, Mich. General view.

granted to Henry Wittekind, of Chicago, on April 14, 1903. The Wittekind piling does not seem to have received any particular attention from the engineering profession and is rather too complicated for ordinary uses.

DOUBLE TEE INTERLOCK.

Mr. Geo. E. Nye has also patented what might be called

the double tee interlock form of steel piling which is represented in patents 753,094 of February 23, 1904; 778,601 of December 27, 1904, and 816,994 of April 3, 1906, all of which are owned by Mr. L. P. Friestedt and which require the manufacture of special rolled shapes before any fabrication can be done.

INTERLOCKING TROUGH PLATE.

It will appear from this discussion as though we had invented sufficient forms of steel piling for all practical purposes, but in addition to rolling shapes, structural mills also roll plates

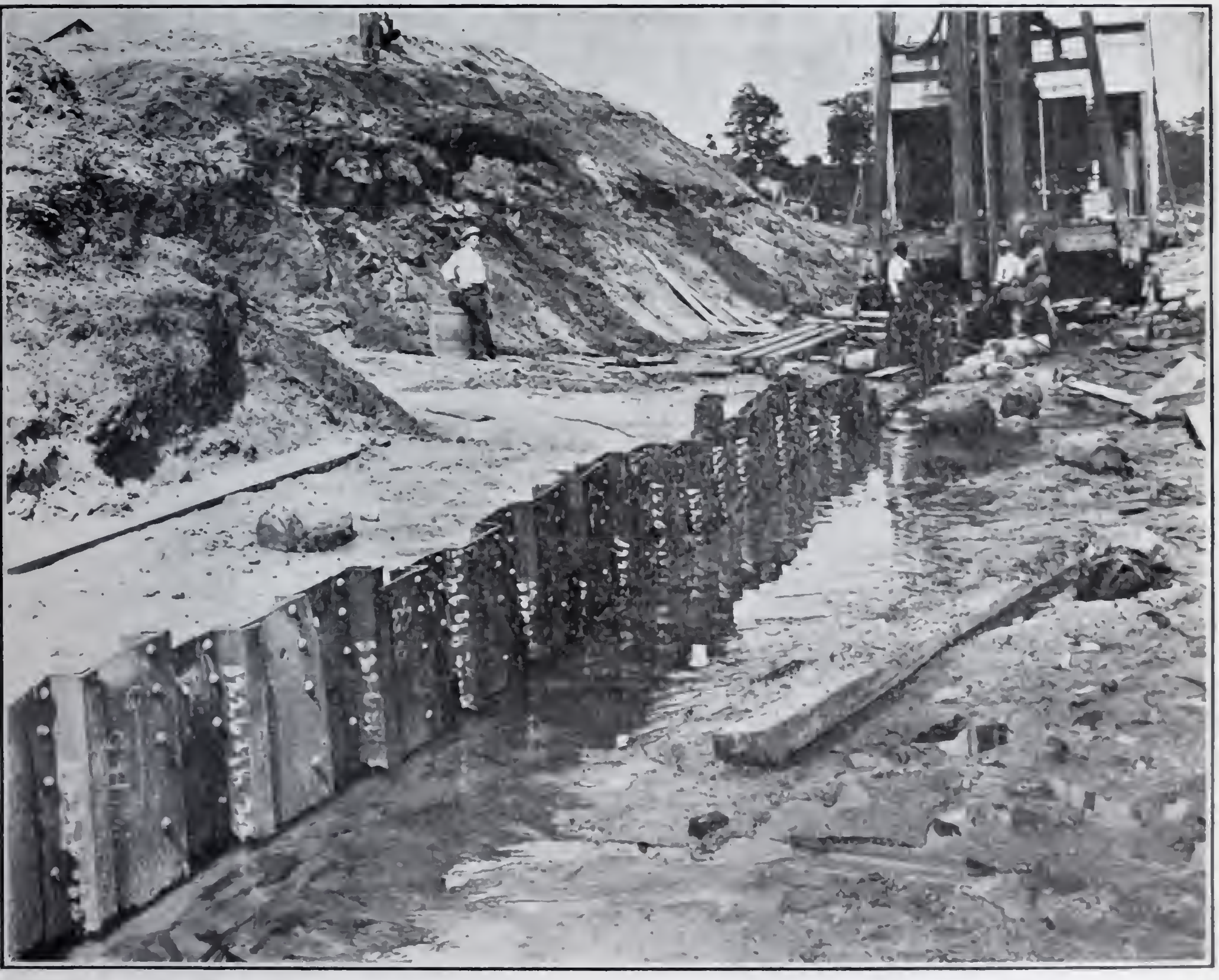


FIG. 11. Dam for Berrien Springs Power Co., Berrien Springs, Mich. Steel Piling Core Wall.

which can be fabricated into various forms and we have the next form of steel piling which may be called the interlocking trough plate type, and cosists essentially of the use of trough plates or similar forms in steel piling construction. Any form of this type of piling would give a large radius of gyration and a corresponding high efficienty of strength. They are, however, difficult to fabricate and are based on a high-priced class of material to begin with. The first patent based on the use of trough plates was granted to Frank N. Kneas, of Chicago, No. 744,361, on November 17, 1903. This was followed by patent 751,469, February 9, 1904, granted to Walter L. Cowles and Jas. N. Hatch, of Chicago, Ills. The ideas of these inventions have been extended and improved upon in patent 801,946 of October 17, 1905, granted to Julius R. Wemlinger, of New York. No form of interlocking trough plate piling has yet been fabricated or driven, and the Wemlinger piling in its latest form calls for very expensive rolling processes to produce the necessary plain sections.

BOX INTERLOCK, ETC.

The use of plates for sheet piling has been a fertile idea in the minds of inventors. Geo. W. Jackson's patent 697,943 of April 15, 1902, covers what might be called the box interlock in which the ends of the plate are bent around into a box form to make an interlock. Patent 824,513 of June 26, 1906, granted to R. H. Stevens, Homestead Steel Works, represents what may be called the *scroll interlock*, in which the complete pile has an end section like the scroll of the engraver, with the exception that one end is of smaller radius of curvature than the other. Lester R. Gifford and R. V. Sage, of Westmont, Pa., took out patents 766,131, 766,132 and 766,147, all dated November 29, 1904, on *corrugated interlock*, in which the sheets themselves are corrugated as in roofing and the interlock is formed by a special rolled shape fitting closely over the apex of adjoining sheets.

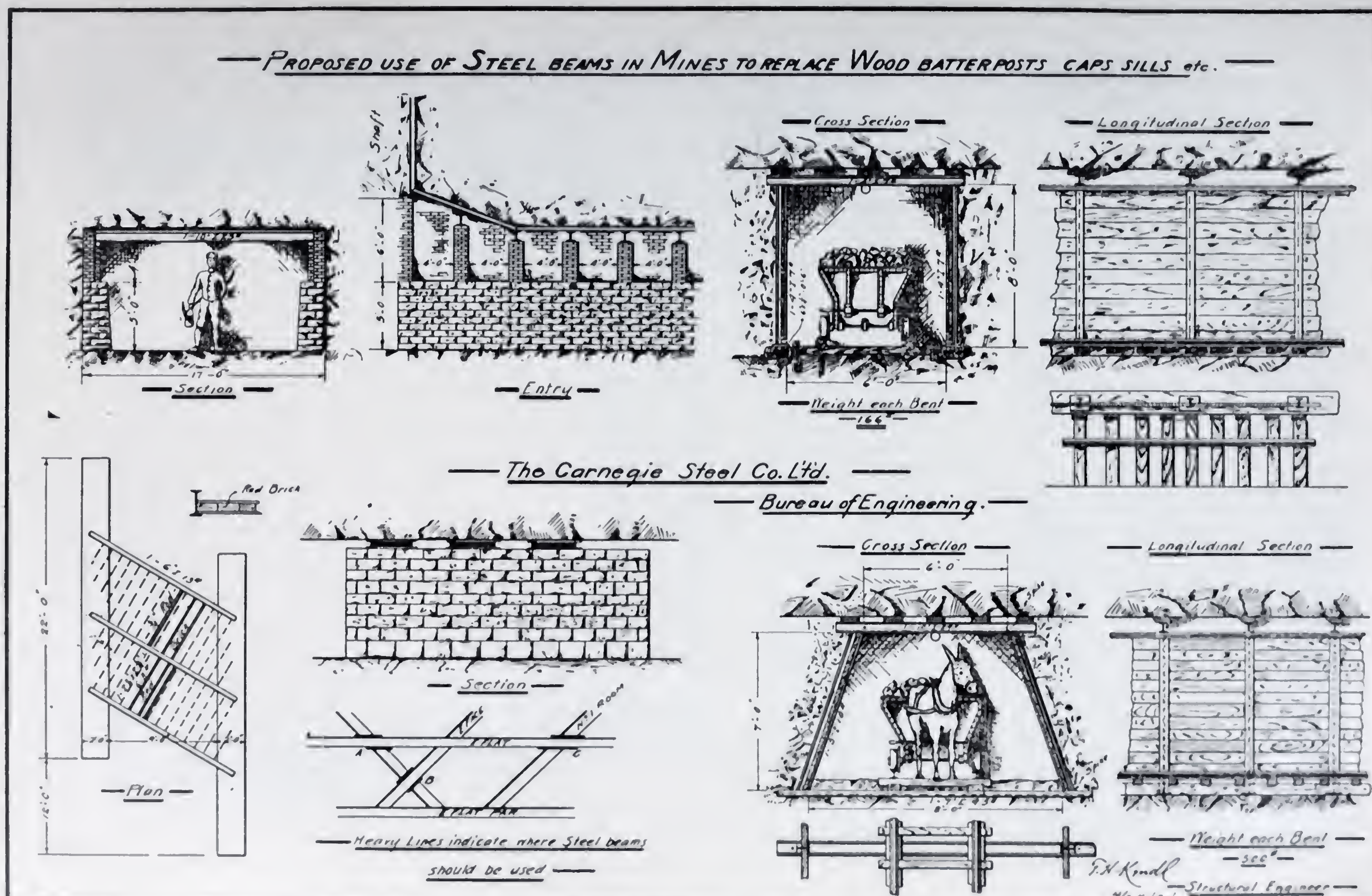
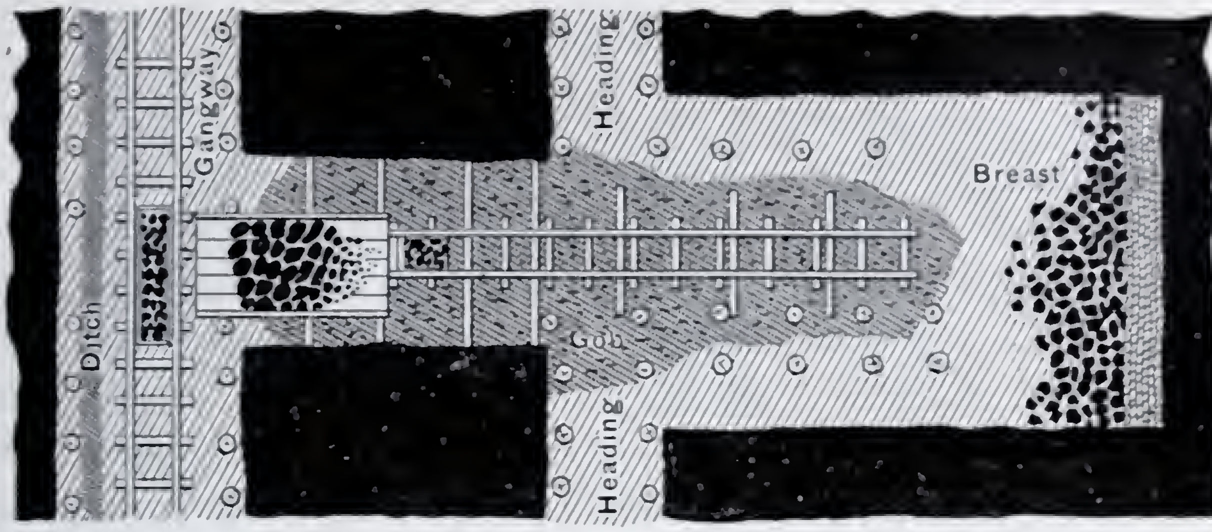

PROPOSED USE OF STEEL BEAMS IN MINES TO REPLACE WOOD BATTERPOSTS CAPS SILLS etc.
Section
17'-6"
5'-0"
Shaft
6'-0"
5'-0"
Entry
Cross Section
8'-0"
6'-0"
Weight each Bent
166
Longitudinal Section
The Carnegie Steel Co. L'td.
Bureau of Engineering.
Red Brick
Section
Plan
22'-0"
16'-0"
Heavy Lines indicate where Steel beams
should be used
Cross Section
6'-0"
7'-0"
8'-0"
Longitudinal Section
Weight each Bent
300
Structural Engineer

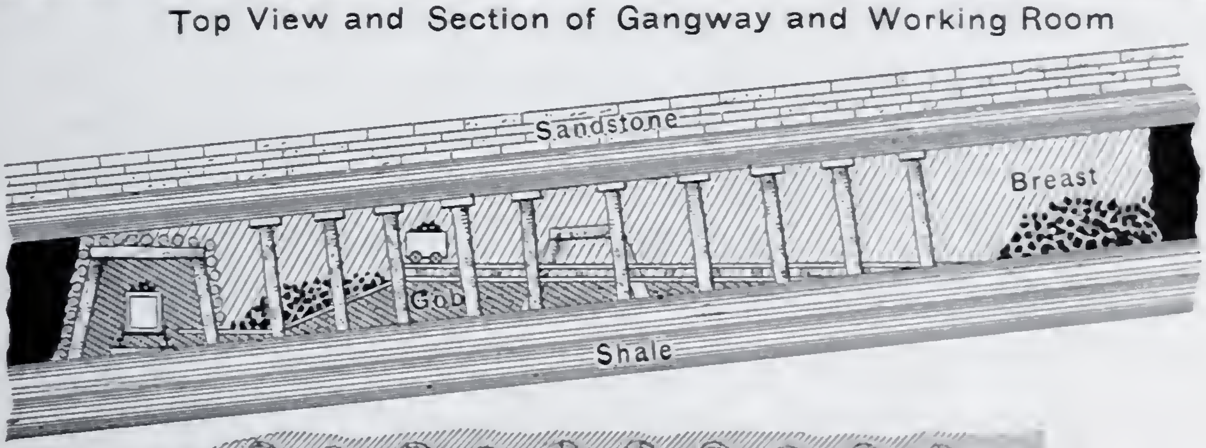
FIG. 12.

SPRING LOCK STEEL PILING.

Steel plate piling, however, finds probably its best representation in the spring lock steel piling, on which patents 842,120 of June 22, 1907, 843,307 of February 5, 1907, and 863,886 of August 20, 1907 were granted to Frank W. Skinner, of New York City, and in which the essential idea is to provide adjoining plates with their ends curved to slightly different radii which in driving compels the sheets to lock closely to each other. The same idea is represented in patent 838,152 of December 11, 1906, granted to John R. Williams, of East Orange, N. J. So far as information goes, no form of plate piling has yet been driven in the United States. The use of plates commends itself to the inventor for the reason that it is possible to get material of different thicknesses and weights to correspond to almost any theoretical constructions. The great difficulty with plate piling, however, is that there is required in connection with the piling itself some form of mechanical device in the way of a follower to go down with the sheets and to hold them in position until bracing can be done, and it is very apparent that the use of these followers, as is necessary with each sheet, calls for not only increased expenditure but delay in the driving itself. There is a very interesting form of plate piling known as the *camber plate piling*, which has had considerable use in Germany and has been discussed in a general way in England, full particulars of which may be found in the Transactions of the Junior Institution of Engineers, March, 1907, in an article entitled "Timbering of Excavations." This form was invented by Mr. F. Lang, of Hamburg, and it has been employed at Hanover for the extensive cofferdam foundation of the Provincial Revenue Offices, and consists of bending vertical edges in specially constructed machines to form a labyrinth U-joint. The plates themselves are bent to a radius of 27 in., which gives a camber of 2¾ in. in each sheet. This form, however, seems to be too cumbersome to meet that simplicity and economy which is required by the engineering and contracting ideals of America.



Top View and Section of Gangway and Working Room



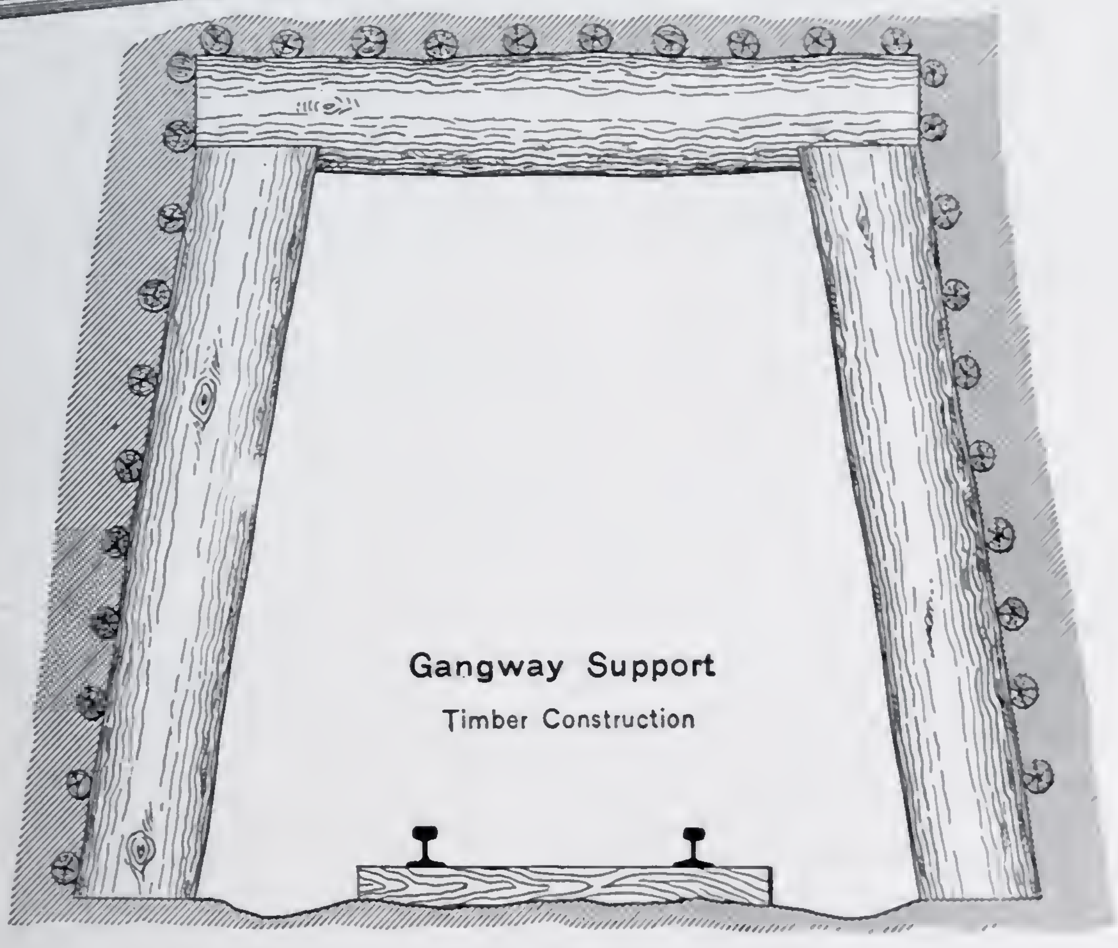


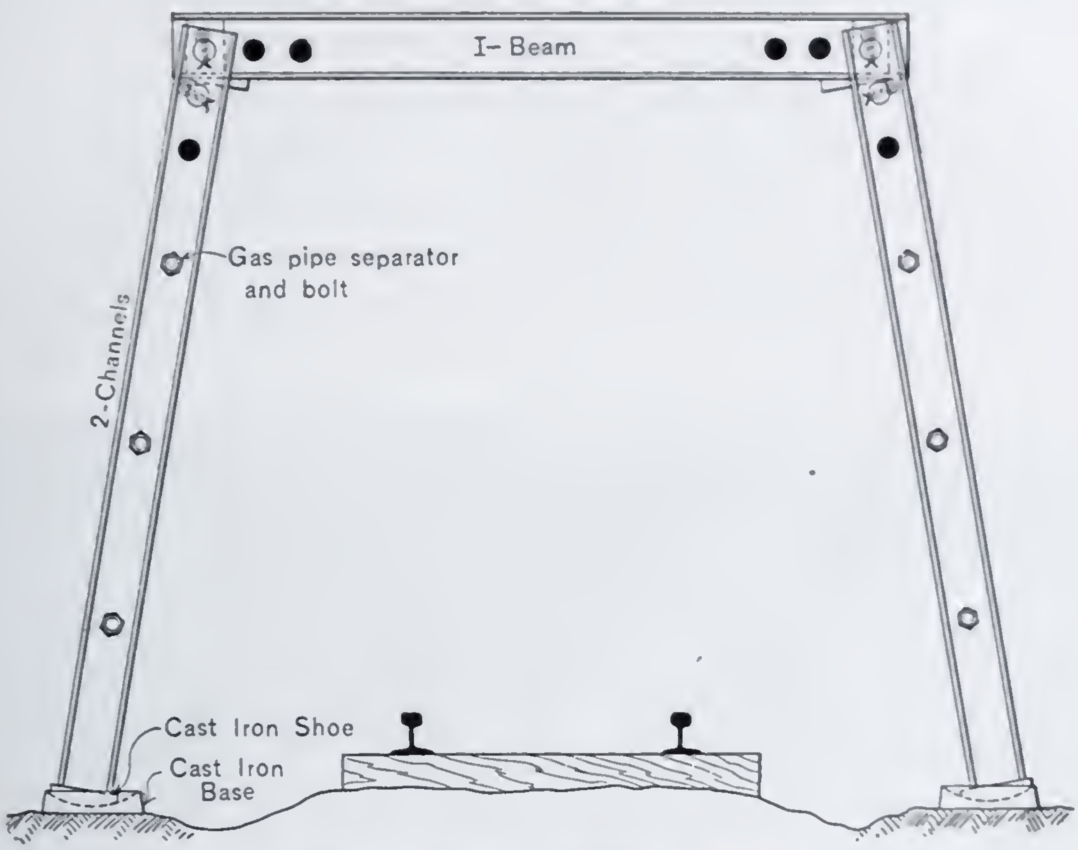
FIG. 13.

ROLLED SECTION.

This exhausts the consideration of the fabricated forms of steel piling. It is apparent to everyone that the ideal steel piling should be complete in itself; that it should be simple; that it should interlock perfectly and that each adjoining piece should have the same theoretical strength. Consequently the ideal form of steel piling should be a rolled section and patents have been granted along this line of various value. The first United States patent covering a rolled section was 103,028, dated May 17, 1870, and granted to Lewis Dodge, of Chicago, for improvements in the construction of tunnels and dams. This patent shows two forms, the ball and socket form with head of one piece fitting into the socket of the other, and the rectangular form in which the connections were made by dovetailing. It is also interesting to note that Mr. Dodge contemplated the use of his section for tunnel lining rather than for sheet piling purposes, an indication of what has often happened in the use of new material which has advantages, that those who built, built better than they knew and that really valuable ideas are developed and extended and improved upon and used for different purposes by the generations that succeed their originators.

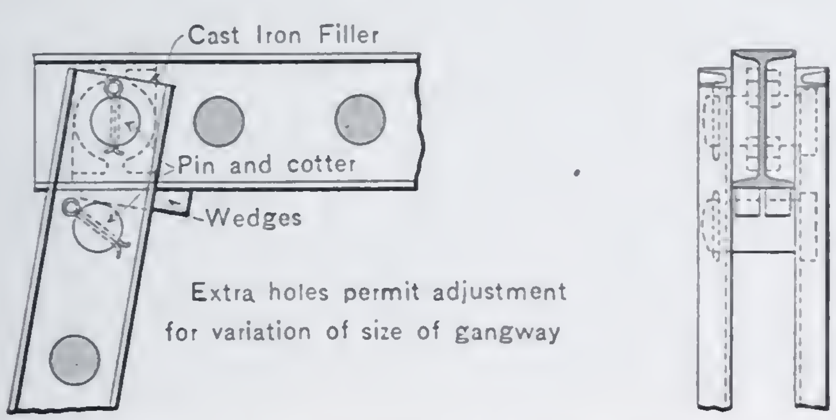
NOVEL IDEAS IN ROLL TURNING.

Practically 65 per cent. of the piling sold today is covered by patent 639,884 granted to Samuel K. Behrend, of Washington, on December 26, 1899, and is known commercially as *United States Steel Sheet Piling*. This piling incorporated the idea advanced by Lewis Dodge, but improved upon by making the section more ideal and by the introduction of packing strips to provide for that water tightness which is necessary in submarine construction. The manufacture of this form of steel piling has also brought forth novel ideas in roll turning. Mr. Walter C. Harder was granted on October 4, 1904, patent 771,426 in which the essential idea was to form an interlocking member by turning over a beam flange so as to form



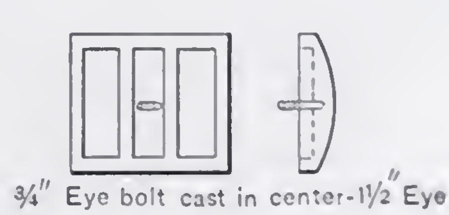
Steel Gangway Support, Style A

Pin Bearing, I Beam Girder, Double Channel Struts, Cast Iron Base



Detail of connection of Girder and Strut

Cast Iron Base



Cast Iron Shoe

FIG. 14.

an interlocking curve. Immediately on the issuance of this patent, its infringement with the Behrend patent was noted. The matter was taken into court and in the court room it was testified that steel piling covered by the Behrend patent could not be rolled by any method known to the art. In spite of this, the Behrend piling was rolled successfully on December 23, 1904, and it was rolled by the special method of rolling in-

FIG. 15.

vented by Edwin E. Slick and covered by patent 852,984 granted May 7, 1907. It is this Slick method of rolling which has made possible the development and success of the United States Steel Sheet Piling.

VANDERKLOOT PILING.

This success has called forth competition, and Mathias R. Vanderkloot, of Chicago, has taken out patents 763,526 of June 28, 1904, and 786,329 of April 4, 1905, covering a form of rolled

section in which an interlock is formed by bending over into hooks the flanges of what starts through the mill as an unsymmetrical beam section. The form of the Vanderkloot piling as actually rolled, represents quite a departure from that shown in his patent, which is only an illustration of the fact that successful invention must go hand in hand with practical rolling mill experience.

Patent 778,354 of December 27, 1904, granted to Rudolph Dobry, represents a form of piling in which the interlock is made by unique dove-tailing. It is needless to say that this form of piling is out of the question from a rolling mill standpoint. The same criticism applies to Geo. E. Nye's patent 782,-872, February 21, 1905, also the very ingenious but far-fetched idea represented in patent 826,801, July 24, 1906, granted to C. H. Quimby, Jr., of Pittsburgh; also to another unique dovetailed form of steel piling covered by patent 829,596, granted to J. J. Nolty, of Canal Dover, O., August 28, 1906.

The Vanderkloot ideas have been followed by Truman Hill, of Chicago, in patent 829,399, of August 28, 1906, in which the interlock is similar to the construction of the modern coupler attachment of standard freight cars.

We are not dealing here especially with composite wooden piling, but reference should be made in this connection to patent 863,837 of August 20, 1907, granted to Francis R. Dravo, of Sewickley, Pa., which represents the ideas of a substructure contractor who has had large experience in driving steel piling himself. It is based on the use of two special rolled steel shapes and wooden fillers in which interlocking means are provided and ample attention paid to the requirements of water-tightness.

Numerous as these piling patents are, the inventors of steel piling have gone so far as to provide special means for driving and for pulling in order to facilitate the installation of the piling itself, and which are really necessary when material is to be drawn and re-used so as to prevent battering of the piling head and closing of the interlock. They have also patented the use of the piling itself. For example, patent 762,042

granted to L. P. Friestedt June 7, 1904, covers by means of steel piling a method of raising subterranean rivers so as to make underground water available for purposes of irrigation. Patent 832,371 granted October 2, 1906, to the same party covers the construction of ship canals, with special reference to the St. Clair Flats, while patent 832,964 of October 9, 1906, deals with the application of steel piling in the construction of building foundations and retaining walls.

USES OF STEEL PILING.

Having described various forms of steel piling now on the market, some of which have distinctive merits and some of which are absolutely without value, we will proceed to consider their uses. Steel sheet piling in general can be used for any purpose for which wooden sheet piling can be used, and its first and most common use is in the construction of cofferdams for building bridges. It is for this purpose that the largest sales of steel sheet piling have been made. Its repeated use in such work has called forth entire satisfaction from its users, its large advantage and great economy consisting in the ease with which it can be driven and the ability to withdraw and re-use over and over again, without serious injury. The cofferdam for the new bridge now being built by the Chicago & Northwestern R. R. across the Mississippi River at Clinton, Iowa, for example, has required about 1166 tons of 40-℔. United States steel sheet piling. There are nine cofferdams to be constructed and steel piling will be used three times. The piling is being driven with a 3200-℔. drop hammer falling approximately 15 ft. Packing strips were not used. There were leaks present in the piling, but not of sufficient size to interrupt the work. In order to rush the work on this job, the C. & N. W. people used a double wall of steel piling with puddle. They admit, however, that with a single wall of piling, using the wooden strips, they would have had practically a watertight dam. Six to thirty piles were driven each working day at a cost of 18c per lineal foot of structure.

The National Tube Company, in carrying out improvements at its Pennsylvania Department, this city, constructed in 1907 a concrete river wall 1660 ft. long. One end of this wall is entirely in the Monongahela River, and the wall runs along the river bank in a direction inclined thereto, so that the other end is in dry ground, the space between the wall and the bank being eventually filled in. This wall was constructed in four installations of three cofferdams each, the piling being driven with a 3600-℔. drop hammer, pulled and

Fig. 16.

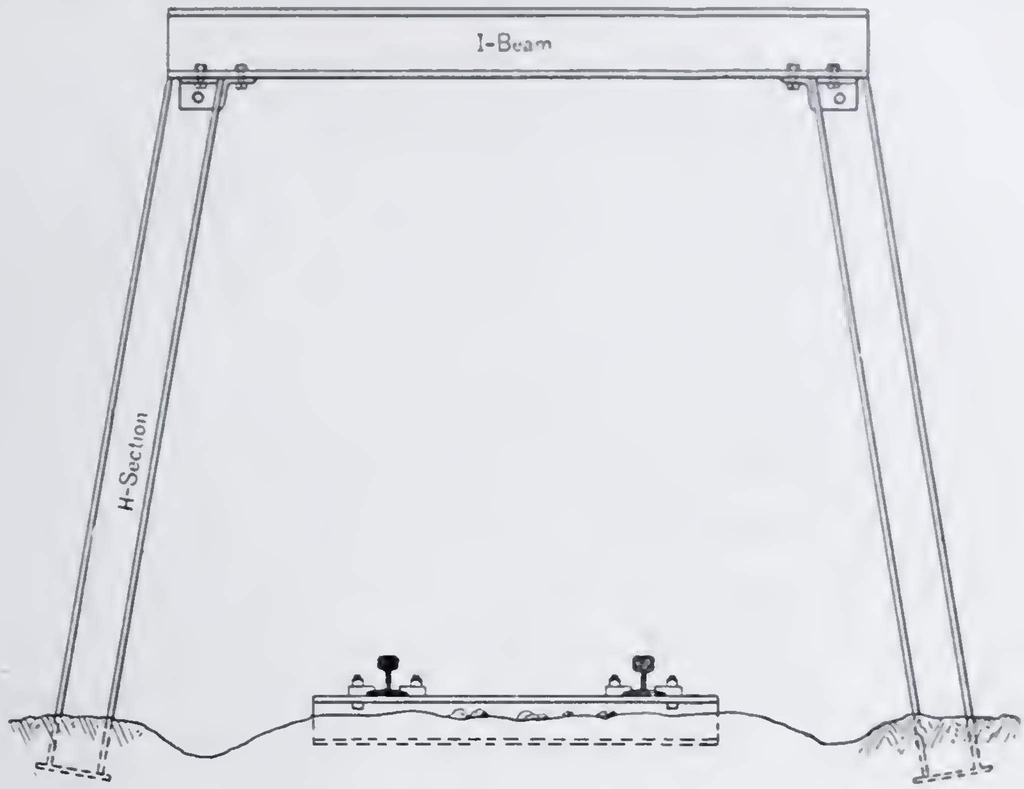
used over again, sufficient piling being purchased for one installation only. Thirty-five pound United States Steel sheet piling was used without caulking beyond the silt and mud found in the river bottom. There were no leaks present of a size sufficient to interrupt the work, which was entirely satisfactory in every respect.

The Marsh Bridge Company have recently built a cofferdam for a bridge pier at Peoria, Illinois, using 130 tons of

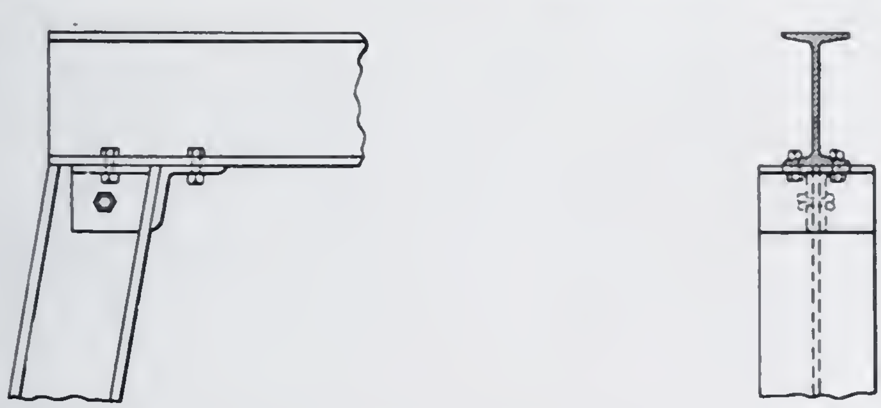
Friestedt 15-in. 38-lb. This material was bought second-hand from the Cullen-Friestedt Company, who had used it for two cofferdams previously. The Marsh Bridge Company have driven it fully three times, making five times in all that the same set of steel piling has been used. Bayne & Hewett, contractors, Minneapolis, Minn., used 15-in. 38-lb. Friestedt piling in cofferdams for government bridge at Rock Island. They installed the same lot of piling four times, driving it down through 17 ft. of sand, gravel and hardpan. No method of caulking was used and yet the leakage interfered at no time with the progress of the work and the cost of driving amounted to only 14½c per lineal foot of substructure. Steel piling in use has met, of course, with all sorts of obstructions. It has successfully penetrated in one case three 16-in. square timbers without any difficulty, but the most difficult driving of which we have record was that encountered by the Hoover & Kinnear Co., at Wheeling, W. Va., in constructing a cofferdam for the Baltimore & Ohio Railroad bridge. Here the material encountered all kinds of difficulties. It was even attempted to drive the stuff through a locomotive axle which happened to be in the debris on the river bank, and while the piling was seriously bent and twisted, and re-drawing was extremely difficult, it was finally accomplished and the second installation proceeded with. In this connection the experience of the Norfolk & Western Railway is instructive. In changing the alignment of their bridge over Paint Creek, near Chillicothe, it was necessary to rebuild the structure which had stood for about twenty years, and absolute comparison between wood and steel became possible, the piers built with wooden cofferdams on the old bridge being only about 250 ft. from the new ones.

RELATIVE COST OF STEEL AND WOOD.

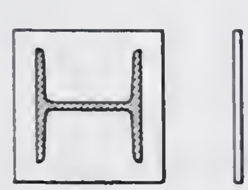
Twenty years ago the contract cost per structure of several certain wood cofferdams was $452.50. At the present time the same wood structure would cost $638.22. United States Steel piling was used five times for five cofferdams within 300 ft. of those twenty years ago and came out of the work



Steel Gangway Support, Style F
I-Beam Girder H-Section Struts, Steel Cap and Base



Detail of Connection of Girder and Strut



Base Plate

FIG. 17.

practically as good as new. Make your own analysis. Apply any method of figuring and the economy of U. S. Steel piling will be strikingly apparent. For instance, after a five-fold use U. S. Steel piling was practically as good as new. Making no allowance for salvage or scrap value, the cost per structure

was $505.09, with piling on hand as good as new. Charge depreciation, on account of a final or scrap value, of from 30 to 35%, and in view of the good condition of piling after using five times, it is hardly reasonable to charge off 10% of the total cost of piling against each of five cofferdams, 41% in all. But even on that basis, the cost per structure would be $289.95 and the piling would be on hand as good as new, possessing a salvage value of 59%, equal to $1,075.68, or a scrap value of say 30%, equal to $546.50. Credit a scrap value, $546.50, pro rata to five cofferdams charged at $505.09 each and the net cost per structure would be $395.79; or credit a salvage value $1,076.68 pro rata to five cofferdams charged at $505.09 each and the net cost per structure would be $289.95. The saving on steel piling on any calculation is apparent.

USE IN RETAINING WALLS, SEWER AND TRENCH WORK.

Steel sheet piling has also been used extensively in the construction of retaining walls, sewer and trench work, and foundations of all kinds. In these instances it takes primarily the place formerly occupied by wood. There are other instances, however, in which steel sheet piling has been used where wooden sheet piling could not be used to an advantage. It has been used by the United States Reclamation Service in the driving of curtain walls to resist underground percolation of water, and has in this way effected a great saving in the reduction of excavations otherwise necessary and in the time consumed in the construction. Along the same lines is its use by the Engineering Department of the United States Government in the protection of the wooden dams in the Allegheny River. During the freshets of the early part of 1907, the wooden dams became undermined and it was also necessary to use dynamite to dislodge the ice gorges which had accumulated beyond them. Also the banks at Springdale with the buildings thereon erected were eroded and swept away by the force of the current. In reconstruction of these dams, and in order to economize where possible, the United States Government decided to drive 40-ft. United States Steel piling

along the entire up-stream face of the dams and along the wing walls. This will most effectively prevent any underscouring action of the water and will make the structure practically perfect.

USE IN DAMS.

In line with this use in streams to prevent underscour, is its use in the construction of dams for hydro-electric projects. The dam at Grand Rapids-Muskegon Power Company, Grand Rapids, Mich., is an illustration of what can be done in this direction, and the same company who years ago constructed that dam, built this year a dam for the Berrien Springs Power Company, at Berrien Springs, Mich. Under previous methods of operation in building a dam across a valley, it would have been necessary to excavate far below the surface of the ground and to construct a masonry or concrete wall as a core to prevent seepage of water below the dam itself. All the expense and delay incurred by this practice has been avoided by the use of steel sheet piling which is driven down to the surface of the ground and the masonry dam built above it.

Along this same line also is the intended use by the United States Government of steel sheet piling in the construction of a sea wall at Fort St. Philip. Here steel piling will be driven and the tops capped with concrete to form the outline of the wall itself. About 1450 tons will be used in this construction.

DRIVING—BRACING.

Steel piling can be driven with any of the ordinary forms of wooden pile drivers. The weight of driving hammers and general equipment will, of course, depend upon conditions of driving, character of soil, length of material and personal prejudices of the contractor. Ordinarily it can be pulled with same tackle with which it is driven, though, like any other class of structural material, its use must be attended by skill and intelligence. There is a question of engineering interest in this connection which has not yet met with a satisfactory solution. This is the whole question of bracing. We do not

know just what reactions are to be met with due to earth pressure, nor in general how earth pressure acts. The December Proceedings of the American Society of Civil Engineers contains, for example, a long discussion on this subject, which is marked mainly by the difference of opinion of those who took part therein. It appears reasonable to suppose that bracing may be made lighter as the depth of the installation increases, and yet any theory, based on the homogeneous character of the soil, will be vitiated just as soon as either hardpan or quicksand is encountered. The whole question at present is a matter of experience and judgment. It is better to put our trust in strong bracing beams than to take chances of serious failure, not that the piling would be destroyed by almost any conceivable failure, but because of the delays and expenditure incident thereto, due to lack of judgment in preparing the bracing. We have in mind the failure of a cofferdam not very far from Pittsburg where the contractor left the steel piling with an unsupported length of 14 feet subject to earth and water pressure. It is entirely probable that a single additional line

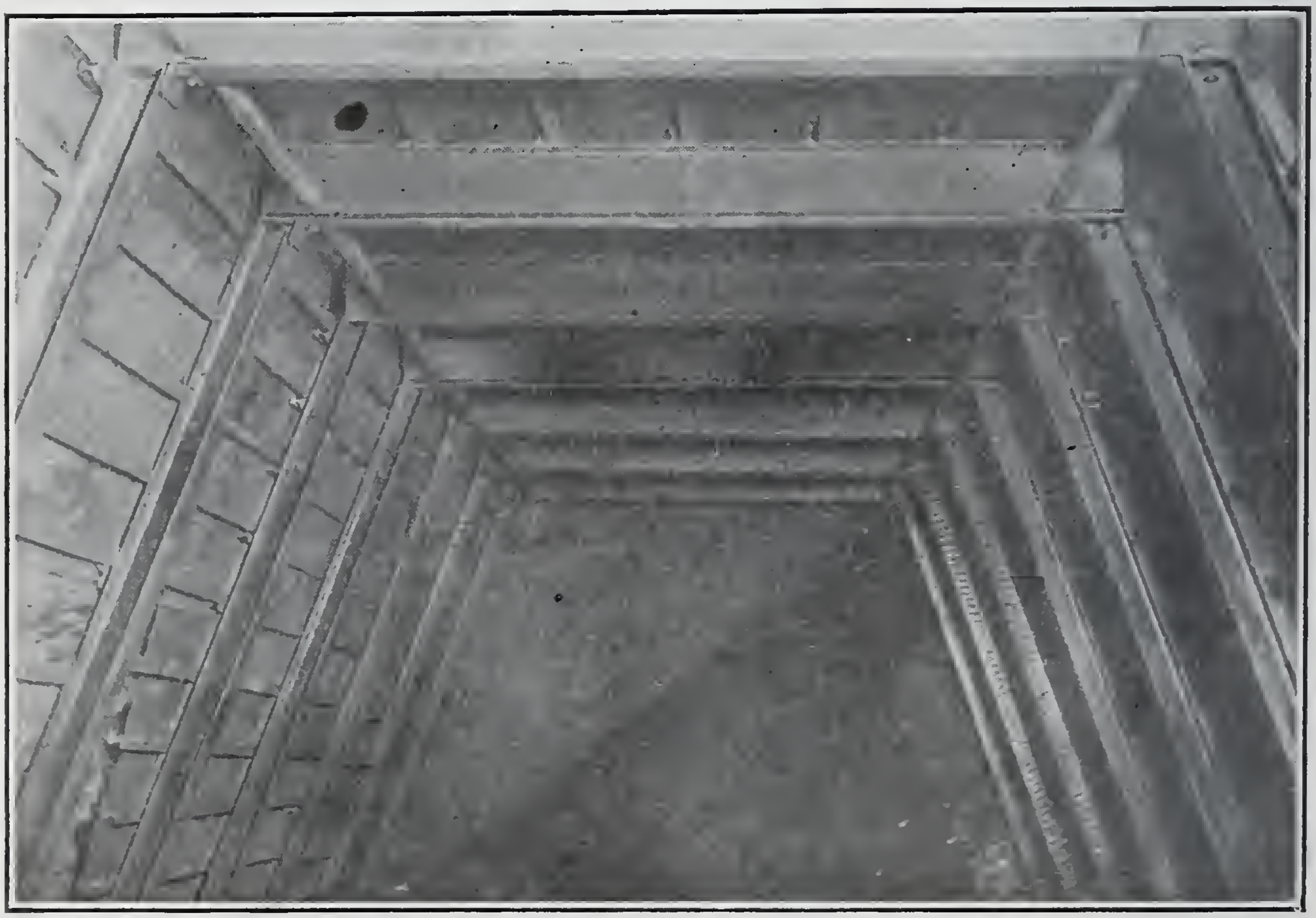


FIG 18.

of bracing at small expense would have made the cofferdam absolutely safe. Any engineering materials, however perfect, must be used with engineering intelligence. So used steel sheet piling commends itself as the perfect modern material of construction.

USE OF STEEL IN COAL MINING.

The next item of interest to us in connection with the new uses of steel is its use in substitution for wood in the mining of coal. Here both factors, of which we have already spoken, find place, for the steel, though primarily to take the place of material which is proving more or less harder to obtain and less economical as the years advance, has this additional quality that it serves to prevent to a large extent destructive fires in mining operations, which in the past years have been the cause of loss of life and property. Here again we meet with the truthfulness of a statement made years ago by an old-time writer that "there is nothing new under the sun." However that may be, it is an unquestioned fact that the solution of problems, as they present themselves to different generations, are for those generations concerned new solutions, and while solutions may be made along the old-time lines which are fixed and certain, yet the solutions themselves demand originality and intelligence in entirely new directions.

The production of coal mined in the United States has increased by leaps and bounds in every decade of the records. Statistics show the following figures for the United States:

Total tonnage mined in the United States—	Gross Tons.
1816	75
1826	147,914
1836	984,832
1846	4,865,522
1856	13,546,925
1866	29,003,583
1876	53,280,000
1886	113,680,427
1896	191,986,357
1906	414,157,278

Along with this increasing production, which has made the United States the foremost coal producing country in the world, so that in 1906 our country mined 37.43 per cent. of the total world production, surpassing even Great Britain in its tremendous output by 47.3%, there has come the rapid exhaustion of such sizes of timber as have been absolutely necessary for the conduct of the mining operations, and the great problem immediately before the coal mining operators is a problem which confronts the very continuance of those operations. The timber resources of our country were once supposed to be practically exhaustless, but when we consider that in 1906 approximately 150,000 acres of forests disappeared down the slopes and shafts of the anthracite regions, 260,000 within the rooms and headings of the bituminous mines—a total of 641 square miles of trees, and more than half the area of the State of Rhode Island, you will note the pertinence of the proposal of steel as the logical successor of wood in coal mining operations. The timber in the mines cannot be looked upon under present conditions in any way as a permanent installation, as the life of timber, especially in the anthracite regions, is so short that the timber requirements must be looked upon by the mine owners as a regular annual fixed charge, and it is conservatively estimated that the entire equipment inside the workings of the anthracite mines in the shape of timber must be replaced in 12 to 18 months. The Forest Service of the United States Department of Agriculture, as the result of elaborate investigations, have reached the conclusion that in the anthracite region 45% of the destruction of timber is caused by the variations in temperature and moisture and the bacterial organisms, 35% by crush or squeeze, due to the displacement of the strata under mining operations; 10% is destroyed by insects, and 10% wasted.

Preservative treatment of the wood has been recommended to prevent a portion of this annual loss. It is, however, generally recognized that preservative treatment is only a partial solution; and that as a last resort the miners of coal must come

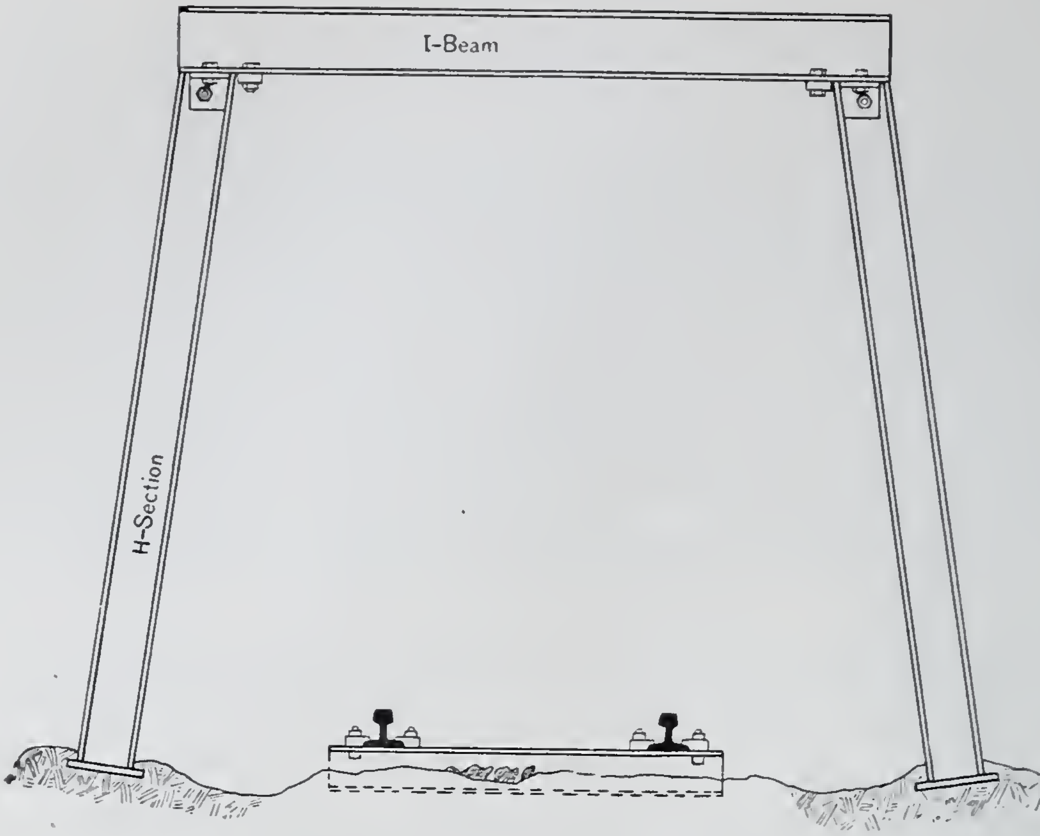
to the remedy used in other forms of building construction and use steel for their permanent installations.

The use of steel in mines is not at present to be looked upon in any way as an experiment inasmuch as there have been in use in the past 12 or 15 years in the mines of the Susquehanna Coal Co. steel timbered gangway supports which have been in use in deep parts of the mines exposed to constant contact with mine water and without signs of failure or corrosion.

The first use of steel by the Susquehanna Coal Co. marks approximately the time when the mine operators of this country began to realize the importance of making provision for the replacement of wood due to its increasing scarcity and cost. It is also a matter of history that about this same time designs were made in Pittsburg for the replacement of wood by steel in coal mining operations in connection with which Figure 12, made by the Carnegie Steel Company on April 24, 1894, will be of interest.

Figure 13 shows the ordinary form of timber used in mining operations in the State of Pennsylvania. It consists of two round sticks of timber, or legs, supporting another stick of timber called a collar, around which are placed small wooden poles to prevent the falling in of the sides and roofs, and to transmit the load on to the timbers themselves. The size of the timber, like the size of pillars, is not determined by ordinary methods of calculation. It depends upon the depth of cover, the character of the roof, floor and coal, thickness of the seam, the presence of gas or water in the strata, and the general method to be adopted in the moving of coal and drawing the pillars. Under present conditions and without the knowledge which in time will come from the careful tests of steel in actual use, the only method by which to determine the proper size of steel timbers is to compare wood and steel in accordance with their theoretical values.

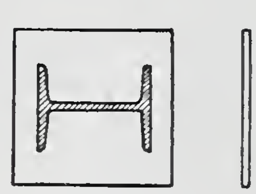
Figure 14 illustrates that form of construction which was designed by Mr. Norris, in which provision is made for



Steel Gangway Support, Style G

I-Beam Girder, H-Section Struts, Steel Cap and Base

Detail of Connection of Girder and Strut



Base Plate

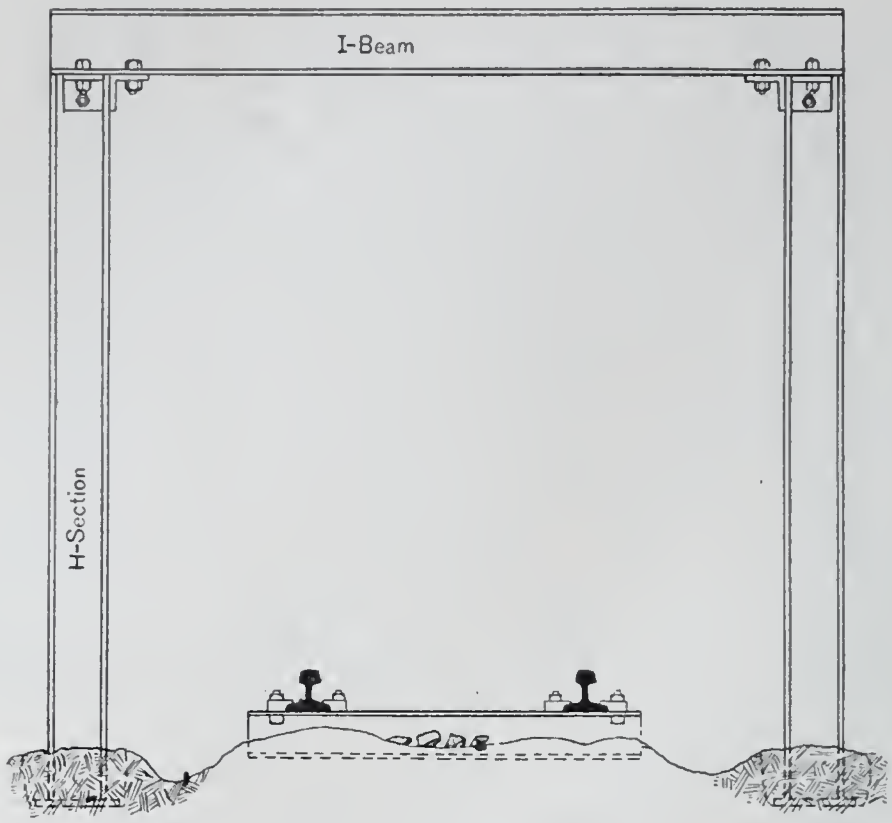
Fig. 19.

adjustability both at the top and bottom, pin connections being used at the top and rocker castings at the bottom. Steel wedges are driven in at the bottom of the beam so as to distribute the weight on two pins, and additional holes are provided to take up differences in levels. It will be noted that in this form of construction it is necessary to assemble one beam, four fillers,

two wedges, four pins and cottars, four channels, four shoe castings, six pieces of cast pipe and six bolts, 31 pieces in all. In ordinary practice beams and channels are bought from the steel makers and castings from a foundry, pins from a structural shop or bridge company, bolts and separators from still other parties, making, as a rule, about four different sets of purchases. This makes the cost of this form of timber comparatively high, and there is needed some form of construction which will be equally strong, but more convenient to manufacture and simpler to erect. It is but fair to say, however, that a large proportion of the steel timber installations now in place have been patterned after this form and where great strength is required, it will be necessary, and simple as well, to use steel beam collars, framed in between double channel legs, as shown in this arrangement.

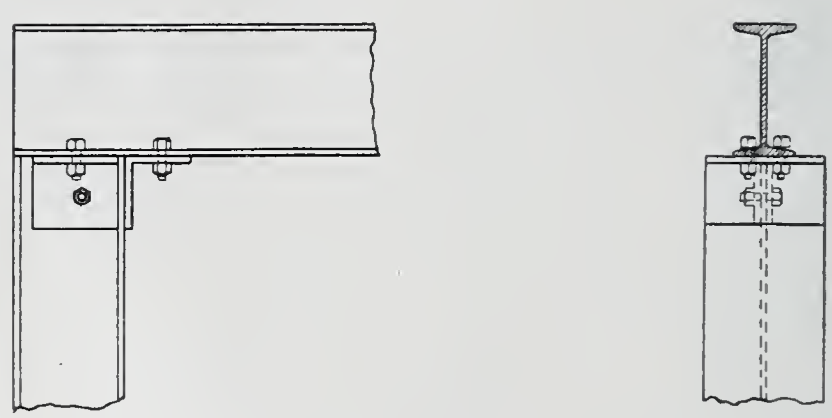
Figure 15 illustrates 125 sets of this general arrangement now in place at the Windber mines of the Berwind-White Mining Company. The collars are 12 in. beams 12 ft. long, the posts are made of 8 in. channels and 1¾ in. pins are used throughout. The plain material was furnished by Pencoyd Iron Works, and the fabrication was done by customer in their own shops. Figure 16 shows a similar installation in the mines of the Lykens Valley Coal Company at Williamstown, Pa.

Observation and experience, however, indicates that adjustability is not needed in the steel timbers any more than in the wooden timbers whose place they are to take. It is also apparent that the problems of erection can be more fully and satisfactorily met if simplicity is made a large feature of the ideal construction, and for the legs of the square mine timbers and for props it has been apparent for some time that in the United States at least the most economical section has not been rolled. Nature builds the strongest sections in the form of hollow cylinders which have the largest radius of gyration for the least given weight of material, and therefore the greatest strength. Round sections, however, are not simple, and

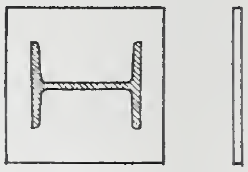


Steel Gangway Support, Style H

I Beam Girder, H-Section Struts, Steel Cap and Base



Detail of Connection of Girder and Strut



Base Plate

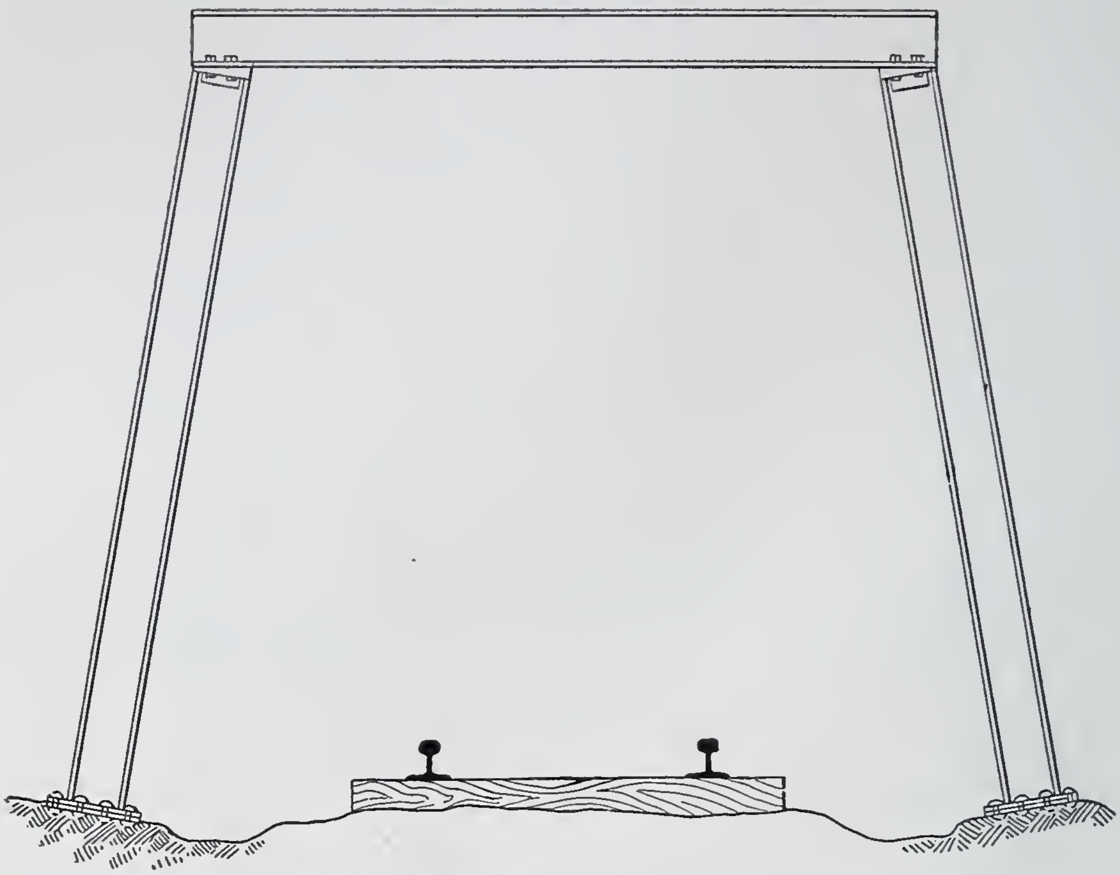
FIG. 20.

to make connection thereto is difficult and intricate. Therefore, it is necessary to look for as close an approximation to circular form as is possible under present conditions. This is given us in the H. section, a form of rolled shape which possesses a large radius of gyration and the most economical distribution of material in comparison to its weight, and which is

especially adapted for use in mining operations. The first manufacturer to furnish these in the United States was the Carnegie Steel Company, and its 4, 5, 6 and 8 in. sections, all of which are now successfully rolled, have been designed especially for use in coal mining operations. The 4 in. section weighs 13.6 lbs. per lineal foot, the 5 in. 18.7 lbs., the 6 in. 23.8 lbs. and the 8 in. 34.6 lbs., which gives a range of sizes sufficient to take care of all of the ordinary requirements of coal mining operations, and whose simplicity is plainly proven in the types of construction shown in the figures.

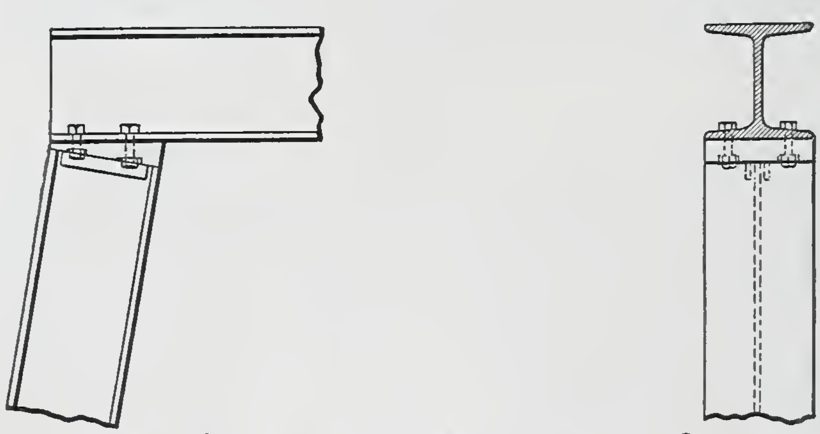
Figure 17 shows perhaps the simplest form of construction adapted for mining purposes. It consists of a beam collar, two H-sections lug angles at the top thereof to prevent side motion, and absolutely plain plates for bearing. This form of construction has been successfully applied in the mines of the Midvalley Coal Company, and is specified for 150 sets of the Lytle Coal Company, and 25 sets for the Pine Hill Coal Company, and is believed to represent the ideal form for this purpose. If the bearing plates are omitted, there are practically three pieces to handle. The set can be put together on the ground, and raised into position with a minimum of difficulty.

Figure 18 represents a form of construction intedtically the same, with the exception that instead of angles, square bars bolted to the lower flange of collar, are used to prevent side motion. This form has been adopted by the Lehigh & Wilkesbarre Coal Company for the construction of about 60 sets square mine timbers at Maxwell Colliery No. 20, Ashley, Pa. When this material is used for pump houses, H-sections can be furnished perfectly square and guide angles at the top also square, as shown in figure 20. Figure 21 illustrates a form of construction adapted for lighter loads where the span is not too great to require more than an H-section as support. It consists of an H-section collar, H-section legs, simple base plates if required, and cast iron cap to distribute the load from the collar to the legs and having protecting lugs

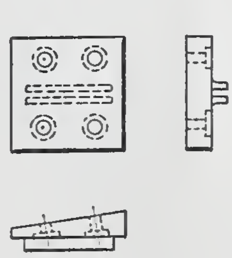


Steel Gangway Support, Style C

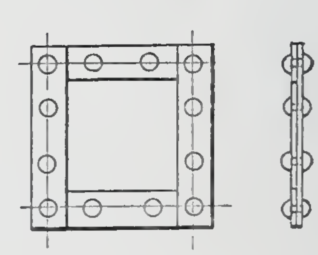
H Sections Girder and Struts, Cast Iron Cap, Steel Base



Detail of connection of Girder and Strut



Cast Iron Cap



Base Plate

FIG. 21.

to prevent undue side motion. With this form of construction, H-sections are absolutely plain. They can be cut to length either at the shop or at the mines, as desired.

The history of these sections demonstrates that which has always happened in the history of all new ideas—a good idea brings with it a succession of others which were outside of the ken of its originator. When the H-sections were placed on the market, their usefulness in other directions became plainly apparent. They will take their place with the ordinary structural shapes, heretofore rolled, in the construction of light columns for all sorts of purposes, and the present range of sizes is sufficient to construct an ordinary five or six-story building. They will also be used for transmission line supports and for other purposes for which ordinary structural material, and indeed timber, is now employed.

DISCUSSION.

Chairman Pittman: If there are any questions that you wish to ask on the paper, I know Mr. Woodworth will be glad to answer them.

Mr. Richard Khuen, Jr.: I do not quite understand how that section you have on the table there is handled. You spoke of some packing to be put in. I do not quite get that.

Mr. Woodworth: The space in the interlock is about 1½ in., and a wooden packing strip is put in there.

Mr. Khuen: Is that driven in afterwards?

Mr. Woodworth: No, it goes in as the piling is driven and is not required in ordinary conditions. In the cofferdam at the National Tube Works none was used at all. The reason is that the piling was driven in the mud of the river and there was sufficient silt and mud crowded into the interlock to prevent the ingress of water. But if you have difficulty with water, you drive down the packing strip as you drive the sheeting. It is the use of the packing strip that makes the advantage of the United States Steel sheet piling over that of the Lewis Dodge patent.

Mr. Khuen: Wouldn't it be hard to drive that in a line? In the Friestedt piling you have something to line it.

Mr. Woodworth: No. In driving a cofferdam you build your walling frame first and that takes care of the line.

Mr. L. J. Affelder: Is there any way to waterproof it after it is down in case a strip is necessary?

Mr. Woodworth: Yes; it might be driven down, but the easiest way is to get some loose material, place it on the outside and let the water carry it in.

Mr. Affelder: One other question. Will you please sketch on the board the form of rolls used to roll the piling you have on the table?

Mr. Woodworth: That is pretty difficult. I can give you the finishing pass. (*Illustrating on board.*) The interlock is formed by the flow of the metal in the rolls. When it goes through the pass behind that it is up on this angle; (*illustrating*), and when it is in the next pass it is in this shape (*illustrating*). Then it goes through the past pass flat. In the first pass it is, of course, a square ingot. The second pass you begin to get the shape of the pile, like this (*illustrating*).

Mr. L. P. Blum: In the driving of those pile is one pile driven down to penetration before the other starts, or is the whole line driven down gradually?

Mr. Woodworth: It all depends on how you are driving. Usually one is driven down at a time, the same as you drive wooden piling. But if you are driving material 60 in. long it may have to be driven in three sections, one section lapped over the other in spliced lengths (*illustrating*). Usually they are driven down one after another as far as you go, unless you hit a boulder, when you leave that one sticking up and drive it down after you see what you have hit and remove the obstruction.

Mr. Blum: Is there a cutting edge on the pile?

Mr. Woodworth: No; it is sharp enough to cut its own way. You would not have any difficulty, ordinarily, unless you strike very hardpan or boulders or something of that kind.

That is what Mr. Fargo had to deal with. He got very heavy driving in the Grand Rapids work.

Mr. A. Stucki: It struck me very forcibly in regard to these I beams last mentioned; it strikes me that they are not only easy to roll but they are also easy to paint in and out. In that respect I think that section is far superior to a circular one, or to a box section or a good many others.

The Chairman: Is this H section rolled under the Grey patent?

Mr. Woodworth: No, this H section is also rolled on the angle, but it could be rolled on an ordinary beam mill. On the angle method of rolling the section is squeezed out just as that piling section is squeezed out.

Mr. Affelder: What is the object in rolling it in that way? By that I mean squeezing it out?

Mr. Woodworth: The object is to get better flanges in the first place and in the second place, for sections of this size, it is a more economical method of rolling. They claim that if you get below the 1 to 6 slope, which we have in the standard beam, it adds very much to the cost of the rolls, and, of course, you do not get the same tonnage out of the set of rolls. That section is only 2% slope, 1 in 50, and on an ordinary mill the cost of that would be very high (referring to the H section). I suppose structural people would like to have all the sections in that slope as it is very easy to punch and you do not get any bad rivets.

Mr. Khuen: That is not designed for a beam?

Mr. Woodworth: No, that is designed for a column or strut. It is an ideal section for light columns.

Mr. Blum: Where these H beams have been used in mines for mine supports, is the lagging between beams just a wooden lining?

Mr. Woodworth: That picture you had of the Midvalley Coal Co. had little old rails behind them. The lagging, as they call it, was made of old rails, put in about 3 or 4 inches apart, just enough to stiffen up the boards. You do not need anything very strong.

Mr. Blum: But the lagging is usually timber?

Mr. Woodworth: The lagging set in mines is usually round poles that they can pick up most any place. In the photograph of the Berwind-White mines they had some ordinary 2 in. plank. In the Midvalley Coal Co. mine they had old light T rails backed with boards.

Mh. Khuen: In the upper floors of most office buildings they have the columns running very light. For instance, a channel column section. On the upper floors they want to run them down to 8 or 6 in. section, and that makes the beam connections almost impossible and if the architect in getting up an office building would change from a box section to a section like that on his upper floors he would have a pretty light column and at the same time something that permits a very good connection to be made.

Mr. Woodworth: The 8 in. H section is good for about 60 tons. They could be used in a light building four or five stories high or could be used in a large building for the upper tiers of columns without any difficulty whatever. There is only one difficulty about rolling and that is that you only get the one weight of section from the rolls. This is 23.8 ℔s. to the foot. If you want to make it 30 ℔s. we would have to get a new set of rolls.

Mr. Jas. A. McEwen: Is it practicable in driving steel piling to use a form to protect the top of it? I notice in some of the photographs the tops are very much deformed.

Mr. Woodworth: Where you want to pull it after you have used it, there is used what is called a driving hood, which is an iron or steel casting that fits down over the head of the piling and which is hollowed out in the top and a wooden block put in the hollow. The pile-driver hammer strikes the wooden top first and the wood cushions the blow on the piling. But you can drive steel piling without a cushion hood. It is a matter of care, experience, judgment and the personal equation of the driver whether you need anything of that sort or not. You will find soils where the piling goes down almost by itself, and other soils where it requires great care and intelli-

gence to drive it. Ordinarily, if we want to pull the piling and use it again, it is safer to use some form of driving hood. Every inventor of steel piling who is successful at all in putting steel piling on the market also invents a driving cap to go with it.

Mr. Khuen: You have to look out for the top of the wooden pile, too, when you are driving it.

Mr. Woodworth: Yes, you do. The short plug of wood 6 or 7 in. long in the driving hood is crushed just like the wooden piles. In spite of being protected with a band of iron, they are smashed in driving. They are good for possibly eight or ten piles.

Mr. M. A. Preston: Do you find in rolling that sheet piling section that the flow of the metal will produce comparatively uniform shapes, or does it vary?

Mr. Woodworth: Comparatively uniform. The 12 in. 35 ℔. section would vary in the opening from 1¼ in. up to 1⅝ in. Of course, the little variation does not in any way interfere with its use for piling purposes. If you had to design connections to it and it had to be exactly 1¼ in. all the way through, you would have trouble.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXIV MARCH, 1908 No. 2

SPECIAL MEETING,

January 14th, 1908.

Vice-President J. K. Lyons

In the Chair.

SMOKE PREVENTION.

By John W. Krause,*

Non-Member.

There is no one subject which is so constantly before the public, especially in our Western States where soft coal is used exclusively for steam purposes, as the smoke question. It is also true that no one subject has been so constantly before our law-making bodies as this same question. In Cleveland, for instance, as early as 1856 an ordinance was introduced to prohibit the use of soft coal in manufacturing plants. Up to that time it had been customary to use cord wood, and the use of soft coal by a manufacturing plant built on the lake shore aroused a storm of indignation.

Since then, so far as I can learn, we have had fully a dozen ordinances passed by the Council at various times, as well as a large number that were simply introduced and then pigeon-holed and allowed to die a natural death.

The present smoke department was the result of an agitation started about seven years ago by the Municipal Association of Cleveland which, after a careful investigation of the meth-

* Supervising Engineer of the City of Cleveland.

ods in use in other cities, finally came to the conclusion that a smoke ordinance was not in itself sufficient to bring about the abatement of smoke; it must be administered by men who instead of depending entirely upon their legal authority would carry on a campaign of education among the manufacturers, giving them the benefit of such data and experience as would naturally be at their command in the carrying on of such a work. The first effective work dates from this time, and, while we are still laboring with this same problem, it is evident to those who have followed the movement that considerable progress has been made in our city.

In the East, the smoke question is not nearly so serious. This is due to the fact that anthracite coal, or smokeless coals, are used almost universally. Still, even there the smoke evil is beginning to creep in, and realizing that "an ounce of prevention is worth a pound of cure," they are passing ordinances prohibiting the emission of smoke.

In Boston they have a smoke inspector who is under the control of the Health Board, but their ordinance exempts all public service corporations and locomotive engines, and very little is being accomplished in the abatement of the nuisance. In New York, the enforcement is also in the hands of the Health Board, but the sentiment against smoke is so strong that offenders are invariably fined for violating the ordinance. As an evidence of the feeling in New York, I might mention the case of one party who used soft coal during the hard coal strike several years ago, and was very promptly arrested. The judge in fining him said he did not consider $18 a ton for hard coal a prohibitive price and that the defendant was not justified in violating the ordinance. Considerable pressure has also been brought to bear on the railroads, and electric engines and hard coal have helped to eliminate the smoke as far as these corporations are concerned.

Enforcement of the smoke ordinance in Philadelphia was put in the hands of the boiler inspector. This ordinance, passed about two years ago, practically exempts the railroads

from its provisions and established a scale for measuring smoke. Section 1 of this ordinance reads as follows: "That for the purpose of regulating the emission of smoke from chimneys, stacks, and flues within the City of Philadelphia and to determine by comparison the degree of darkness of smoke so emitted, a color scale of measurement shall be and the same is hereby adopted as follows: One thickness of gray glass of sufficient capacity to cut off 60% of the light from a volume having a lighting power of sixteen candles shall be taken as the basis of said scale, and four thicknesses of such glass shall be known as No. 1 scale." The provisions of this ordinance do not apply between the hours of 4 and 7 o'clock in the morning, when fires are being started. Very little has been accomplished under this ordinance and it is doubtful whether its provisions would stand the test of the courts.

In Cincinnati, where an ordinance was passed using the Philadelphia ordinance as a model, Judge Bromwell, of the Common Pleas Court, discharged the defendant and rendered the following decision as to the validity of the ordinance: "It has been held that the court may take cognizance of and recognize that dense smoke is a nuisance, but there is nothing in this ordinance which shows that the smoke is dense, black or gray. The language is exceedingly vague both in the ordinance and the affidavit on which the arrest was made in this case. The latter charges that the defendant did unlawfully permit the emission and escape from the stack, of smoke of a greater degree of darkness than four thicknesses of gray glass. Now what is meant by 'than a greater degree of darkness than four thicknesses of gray glass?' It is evident that this language can convey no clear impression of what the Council intended."

The President of the United States has taken official notice of the smoke nuisance in Washington and at his request Congress has passed stringent laws on this subject.

Chicago has had a Smoke Department for more than fifteen years and has gone through the various stages of the

smoke movement. For years the campaign was waged along the lines of education, later a strict policy of prosecution was inaugurated. In the year 1906 over $20,000 in fines was collected from smoke cases. During the early part of 1907 the sentiment seemed to be so strong in favor of a campaign of education that the department was reorganized with that object in view. After several months of moral suasion the new inspector finally decided that the best results could only be obtained by a campaign of the two methods. In other words, where offenders agree to make radical changes, plenty of time is given in which to make such changes. Stubborn cases, however, are haled into court and given the maximum penalty. And so I might go on and give you a history of the smoke movement in every city.

Baltimore, Indianapolis, St. Louis, Milwaukee, Toledo, Detroit, Denver, Dayton, Cincinnati, Rochester and Syracuse all have departments for dealing with this question. The people of this country are demanding that this nuisance be abated and slowly but surely means will be found to carry out their wishes.

A large part of the success of smoke abatement depends, of course, upon the attitude of the courts in the various States where such ordinances are being enforced. Much confusion results from the failure to distinguish between the right of a community to abate a public nuisance which is inherent, and in regard to which the one important thing is to prove the thing complained of to be a public nuisance, on the one hand, and the purely statutory right of a community to deal with that which the legislature, or a municipality, properly exercising a delegated police power of the legislature, declares to be a nuisance. One right is a common law right raised by the facts, the other is a right lying within and under the broad discretion of the legislature in the exercise of its police power. In regard to the common law right, it is the duty of the court in every case to decide whether the facts constitute a nuisance.

In regard to the statutory nuisance, assuming the proper exercise of the police power of the State, it is the duty of the court to decide whether the facts constitute what the legislature had defined as a nuisance.

In Ohio the legislature gives the councils of municipalities the right to regulate and compel the consumption of smoke. In the case of Sigle vs. Cleveland the courts decided that the grant of power must be strictly construed and followed by the City Council in enacting an ordinance. The court goes on to say that the legislature did not authorize the council to declare smoke a nuisance, but did authorize the city to regulate it and prevent injury and harm from it. This the council might do by making the failure to use a smoke consumer, or by permitting the smoke of a chimney or stack to annoy any person, or injure property a penal offense and punishing any person for violating the same.

In New York, where the enforcement of the ordinance is in the hands of the Board of Health, the court held that Sec. 134 of the Sanitary Code imposing a penalty on the proprietor of a factory for not so constructing his furnace as to consume smoke was not unconstitutional; but with the proper exercise of police power of the State, and that the Board of Health rules became of statutory force and were a properly delegated use of that power, subject to the same restrictions as other legislative acts, that is, that they be reasonable and not oppressive in their operation. The term "dense smoke" was also held to be not inclusive of all smoke whatsoever, inasmuch as the act was not intended to stop the running of any railroad or factory, but rather in the sense of injurious smoke.

In Michigan the courts upheld the smoke ordinance and it was further decided that the exemption of dwelling houses did not render the ordinance unconstitutional.

The Supreme Court of Indiana rendered a similar decision.

There is a long line of cases in Illinois, beginning with and based upon Harmon vs. Chicago, which have been of much

weight in this country in the decision of cases in this subject matter. Under the general power to declare nuisances and abate the same, the City of Chicago passed an ordinance against the emission of dense smoke, including a section dealing with tug boats, locomotives, etc. In the case named, the highest court in the State held that the State has all powers necessary for the protection of the property, health and comfort of the public, that it may delegate this power to local municipalities in such a measure as may be deemed desirable for the best interests of the public. With regard to the term "dense smoke," the court holds that it will be used as commonly employed.

The Supreme Court of Minnesota in a decision upholding the smoke ordinance, held that the words "dense smoke" were not open to the objection of being vague and uncertain. The court says it would understand by dense smoke precisely what everybody else does who has even seen a dense volume of smoke coming from a stack or chimney where common soft or bituminous coal is used for fuel in considerable quantities. ties.

The Supreme Court of the United States speaking of the broad powers of the legislature says that the State may interfere wherever the public interests demand it, and in this particular a large discretion is necessarily vested in the legislature to determine not only what the interests of the public require, but what measures are necessary for the protection of such interests.

It would seem that where ordinances have been drawn and passed under proper legislative authority, the courts have been inclined to uphold the same.

The question of such legislative authority is one of the things which formed the chief topic of discussion at the last annual meeting of the International Association for the Prevention of Smoke, an organization composed of public officials from different cities in the United States and Canada intrusted with the enforcement of the smoke laws, and a number of pub-

lic-spirited men who are interested in smoke abatement from an aesthetic standpoint. The result of this discussion was to instruct the Executive Committee to have ready for submission at the next annual meeting a uniform law which might be adopted by the legislature of each State where such a law was not already in force. The next step will be the recommendation of a uniform city ordinance to be adopted by the various cities where the smoke evil is prevalent. The advantage of such a uniform law is apparent. A decision in one State will establish a precedent for every city where the ordinance and legislative authority are the same.

A prominent merchant of Chicago, in speaking of the damage caused by smoke, made the following statements which are startling, to say the least. He says that after a careful investigation of the reductions made necessary in his store during the last year because of soiled goods, he found that they amounted to nearly $200,000, and he also estimated that the total reductions in price in State Street annually on account of black smoke amounted to $2,000,000. What would be the total loss in the City of Chicago if the loss in one business street amounts to such a figure?

The Cleveland Chamber of Commerce, in a pamphlet issued about a year ago, made a careful estimate of the damage caused in Cleveland, and it may interest you to know the result of their investigation. The report says: "The most tangible results from the smoke nuisance can be shown, perhaps, in the financial loss to the community. It is, of course, impossible to set forth anything like the total loss. A few carefully compiled estimates, however, from actual experience will suffice to indicate something of its magnitude. There are approximately four hundred retail dry goods stores in Cleveland doing a business of from $10,000 to $3,000,000 or $4,000,000 a year. The owners of some of these stores estimate, and the same estimate is given in other cities, that of all white goods sold, a clear loss of at least 10% must be figured. Taking the single items of underwear, shirt waists, linens and white dress

goods, for the eleven department stores, the proprietors conservatively estimate their combined loss at $25,000. Consider, then, the loss in all lines of light goods for all four hundred stores. The wholesale dry goods houses show a similar loss. There are in Cleveland fifty-five men's furnishing stores, and the conservative estimate of loss to these stores is placed at $15,000 annually. It is a simple matter to distinguish between the soil from ordinary dust and that due to the presence of coal smoke and gas. The former is easily removed; the other, due to an air saturated with smoke, is absorbed, rendering the fabric practically beyond redemption, from the standpoint of the salesman. The stores mentioned represent only a small proportion of the trade directly affected. One hundred and fifteen tailors, twenty-nine cloak and suit manufacturers, forty-nine millinery establishments, eighteen hat and coat stores, thirteen skirt manufacturers, three collar and cuff manufacturers, and many other trades are affected in a similar degree. Aside from the damage to stock, an annual cost for cleaning, particularly among retail houses, must be included. Some conception of this loss may be had from a single instance. One retail establishment paid in just a year after the painting and decorating of its walls and ceilings, $1,800 for repainting and decorating, made necessary entirely by the effect of smoke. During the same year their bill for window cleaning was $2,000; for laundry purposes $1,500. This, in large measure, was due to the smoke nuisance. Multiply these figures by the thousands of business houses needing the same attention, in greater or less degree, and some estimate of the total cost in this direction may be obtained. To this should be added the cost of lighting, particularly in retail stores, factories and offices, made necessary by the smoky atmosphere. Some of the larger houses charge several hundred dollars to this account.

But a greater cost than all of these must be considered in the loss to the one hundred thousand homes of Cleveland. The constant need for cleaning of walls, ceilings, windows, carpets, rugs and draperies, for redecorating and renewing, can be real-

zied only by the house owner or housekeeper. To this add the increased laundry bills for household linen, the dry cleaning for clothing, and the great additional wear resulting from this constant renovation, thus necessitating frequent renewal. Consider also the permanent injury to books, pictures and similar articles. Though impossible of computation, it will be seen that the total of these items aggregates millions of dollars. The annual tribute which Cleveland must pay to the smoke nuisance is a sum sufficient in a single year to equip all plants not so provided, with smoke preventing devices.

This report shows clearly what every community where the use of soft coal is almost universal is losing as a result of this pollution of the atmosphere.

It is difficult to determine to what extent the health of a community is affected by the presence of smoke and gases in the air. Dr. C. A. Reed, of Cincinnati, in an address, made some statements which, coming from such authority, are well worthy of consideration. "The slight morning cough with the equally slight expectoration of black mucous, is an experience familiar to the denizens of smoky cities, but an experience which to the medical mind suggests a persistent though slight irritation of the upper air passages that are thus made hospitable avenues for tuberculosis infection. Physicians of smoke-ridden cities testify to the greater frequency there of cartarrhal and other disorders of the upper air passages. But the trouble is not alone physical. It is not, on the face of it, a good thing for any community to become too tolerant of dirt. Physical dirt is close akin to moral dirt and both combined lead to degeneracy. Another effect of smoke in the air is to shut off sunlight and, as in the case of shrubs or plants, the human system thrives best when there is plenty of bright sun. Take a plant and set it in a dark place; in a short time it begins to deteriorate, and if left there long enough it soon ceases to be attractive to the eye. Put it back where it can receive the rays of the sun and in a short time it will have regained its former healthy appearance. The St. Louis Forestry Depart-

ment estimates a loss to trees and shrubs of 4% annually as a result of smoke and gases in the air.

CAUSES OF SMOKE.

The important questions to be considered are:

Is smoke necessary?

To what extent can it be abated?

Are the devices in use at the present time giving good results?

This is practically summing up the whole problem of smoke abatement, except that we might add one more question: How much depends upon the intelligence of the men who handle these devices?

Popplewell in his book on "The Prevention of Smoke" answers these questions in the following concise words: "Whilst it is certain that smoke can be almost entirely and completely prevented from steam boiler chimneys, the conditions of working are so varied that no single arrangement can be expected to meet every individual case, and further, whatever device is applied to a boiler will in a great measure depend upon the intelligent handling and management which it receives on the part of those to whose care it is trusted."

In Cleveland, we have a large number of plants operating practically without smoke: on the other hand, we have plants equipped with the same devices that are anything but smokeless. The question naturally suggests itself, "Why should a certain device be successful in one plant and not be just as successful in another?" There may be a number of reasons for this, or any of a number of reasons may be sufficient to cause a smoky stack. It may be a question of insufficient draught, or it may be due to overcrowding of the boilers. The load may be variable, or the help in the boiler room may be incompetent. The quality of coal has a good deal to do with the appearance of the stack, or it may be a question of running the boilers so much below their rating that the device is unable to do its work properly. Many devices which are entirely satisfactory with certain fuels and under certain conditions are absolute

failures under other conditions and with other fuels. I have seen cases where a new plant was installed with the most modern devices, good stacks and with every precaution against the emission of smoke; in a short time the business had increased to a point where it was necessary to crowd the boilers so far beyond their capacity that the stack showed a continuous stream of smoke, or, as happens sometimes, a plant may be ample to carry the load at the time it is built, but as the business increases new boilers are added and the stack is soon inadequate to supply the draught to carry off the waste gases. Stacks may be overworked or underworked so as to bring about impracticable conditions in the boiler room. It is difficult to foresee what the needs of a power plant may be five years hence.

I might cite one case where a new plant was built and three boilers were installed to replace the old plant. Before the plant was finished they had already decided to install another and this was followed by a fifth boiler. An evaporative test of this plant made last summer showed that these boilers were developing almost 2800-H. P., and all this was being done with a stack originally built to serve three, or at most, four boilers.

Incompetent firemen are responsible for a great deal of our trouble. I have seen cases where a fireman was unable to operate his plant and keep up steam without creating a nuisance, and where a new man would step in and operate the same plant with ease and a clean stack. Instructions in firing and intelligent proficiency on the part of the fireman are essentials to the proper discharge of his duties. He handles money, and if his qualification is merely strength to heave fuel through the firedoor, an everyday waste of coal occurs. The examination and licensing of firemen would make it possible to place upon this employe the responsibility to get the best results the plant and fuel admit of.

The report of the Hamburg Smoke Abatment Society lays great stress on the improved efficiency obtained by the instruction of firemen in the proper performance of their duties.

Up to October 1, 1903, one hundred and twenty (120) firemen had been specially trained by the officers of the society, and by December, 1904, this total had been increased to three hundred (300).

As an evidence of the loss of efficiency of steam raising plants due to this one cause alone, the following figures are given in an earlier report.

Thermal efficiency with the regular, but untrained fireman, 66.6%.

Thermal efficiency of the same plant with trained fireman, 72.7%.

In the plant where these tests were made, this loss of 6.1% in the fuel efficiency represented a loss of $8.50 per day, or $50 per week of 144 hours.

In another test the loss due to the use of untrained stokers rose 16.11%, the thermal efficiency being increased from 66.8% to 82.9% by the mere change of firemen working at the plant.

In this connection, the engineer of the Hamburg Society emphasizes the fact that the attempt at smoke abatement by untrained stokers without scientific supervision generally ends in failure.

It is true that one of the most important duties of any smoke department is the instruction of firemen, and where such instruction is intelligently received and carried out, the results are soon apparent.

In electric railway or electric lighting or power plants the load may vary to such an extent that it is necessary to have a certain number of boilers in reserve with banked fires during part of the day, so that when required for peak loads they may be easily put into commission. This operation is always attended with heavy smoke and is practically equivalent to building new fires.

In many of our steel plants the load is apt to fluctuate, and even in large office buildings the demand for steam is almost doubled at certain times in the day.

Automatic dampers are frequently responsible for the

stack showing heavy smoke. This is due to the damper closing and cutting off the air supply at a time when the furnace may have a heavy charge of coal from which the volatile matter has not been given off. In one instance I have seen a stack, which up to the time the damper was installed, was absolutely clean, show a heavy puff of smoke five times in as many minutes as the damper opened or closed with the variation in the steam pressure.

The application of a steam-impelled air-jet entering under the arch from the side about half-way between the front and end of the arch and arranged to operate automatically as the damper opened or closed, entirely did away with this difficulty.

Baffles are seldom considered seriously, yet it is more difficult to abate smoke where vertical baffles are used than is the case with those placed horizontally, and I know of instances where the removal of much of the baffling provided by the boiler-maker has afforded the greatest relief, due to enlarged passage for the gases.

Breeching is sometimes found to be inadequate, retarding the travel of gases, so that undue heat bottled up in the furnace melts the brickwork and fronts quites as seriously as lack of stack capacity.

PREVENTION OF SMOKE.

It has been true in the past in the iron and steel industries that the value of a manufactured product exceeded so enormously the cost of the fuel used that little attention was paid to fuel economy. Much has been done in the engine room towards the economical use of steam after it is generated. We have the feed water heater, the compound engine and condenser, cooling tower and the superheater. Losses in transmission are being eliminated. Long lines of shafting and thousands of feet of belting are being thrown away and replaced by small copper wires and electric motors. All this expensive equipment to effect economy, yet, until recently, these steps towards economy have stopped at the boiler-room door.

It is a fact well known that when an engine is once adjusted, if kept properly oiled, it will run a long time with very little attention. In the boiler-room there is need of constant attention.

Business men usually regard smoke agitation unfavorably when first initiated, treating such a campaign as a movement to impose impractical requirements on steam plant owners. As the campaign progresses they are forced to study conditions in their own plants, with the result that very often they find this has been one of the weakest points in their business system.

I have known cases where six pounds of coal was burned to produce one horse-power at the boiler, while in good practice three or three and a half pounds of coal suffice. The average business man would hardly care to pay from 50 to 100% more for any commodity than his neighbor if he knew it, but very often he does not know it until the knowledge is forced upon him.

One manufacturer who had equipped his plant with stokers was so pleased with the results that he voluntarily wrote a letter informing me he was saving $10 a day with his new equipment, and yet in this case it was necessary to threaten prosecution before he would take steps which he afterwards found to be a benefit rather than a hardship. I might mention also that his plant, from being one of the worst plants in the city, became one of the best, showing an absolutely clean stack at all times.

Fifteen or twenty years ago the possibility of preventing soft coal smoke was doubted by many and very few people regarded this subject seriously. Persistence and ingenuity have triumphed in this as in other similar problems, until today there is a large number of stokers and smokeless furnaces doing excellent work. These may be roughly classified under the head of mechanical stokers, steam jet devices and smokeless furnaces. Mechanical stokers may be again divided into three types—the chain grate, the inclined grate, in which the grates may slope downwards either from the front or the side,

and the underfeed stoker, of which there are several types. The principle involved in the operation of these stokers is essentially the same, a uniform supply of air and fuel is furnished which, under normal conditions, should result in a smokeless stack and a high economy in evaporation.

There are many points in favor of the mechanical stoker —ability to burn coal cheap, the advantage of more uniform steam pressure and the saving in labor due to the installation of overhead coal conveyors. The latter carries with it a cleaner and more presentable boiler room.

It is important that care should be used in the selection of stokers. Some installations and conditions are better suited to one type and some to another, and it is of great importance that the owner be sure that he has the type best suited to his conditions. In order to secure perfect combustion several conditions must obtain: The air supply must be sufficient; the intermingling of fuel and air must be complete and thorough so that every minute particle of each comes into direct contact with the other. A temperature at which combustion takes place must be maintained until combustion is complete. The absence of any of these conditions results in imperfect combustion and is likely to result in black smoke.

In the mechanical stoker we have such a uniformity of fuel and air supply, but in the case of hand-fired boilers every one of these conditions is violated. The coal is fed intermittently, usually in large quantities, thereby reducing the temperature of the furnace and causing the volatile matter to be given off at a temperature much lower than that at which combustion takes place. Then again, when a large quantity of coal is thrown over the fire, the air supply is choked just at the time when a maximum amount of oxygen is needed to combine with the volatile hydro-carbons to complete combustion.

In a hand-fired furnace, if the air supply is sufficient at the time when fuel is supplied to the furnace, it is too great for good economy after the gases have been given off, or, if arranged for conditions of best economy, it is not sufficient for a smokeless condition of the stack at time of firing. To over-

come these conditions, it is customary in hand-fired plants to introduce steam jets over the fire which serve the double purpose of inducing a draught of air and at the same time mixing this air with the gases given off by the coal.

Smokeless furnaces, of which the Hawley down-draft is an excellent type, are admirably suited for heating plants, or plants where the conditions are such that it is not necessary to crowd the furnace.

With the advent of apartment houses a new condition has presented itself. These buildings are usually heated with sectional boilers carrying low pressure steam, making it impractical to adopt any of the ordinary devices for preventing smoke. The only remedy in such cases is the use of some fuel, low in volatile matter, such as coke, hard coal or semi-bituminous coal. The latter is the method usually adopted. Consumption of semi-bituminous coal has grown enormously in the last few years as a result of the efforts of smoke departments in compelling the abatement of smoke from such buildings.

The fact that a plant is equipped with a certain accepted stoker or device does not mean that its stack will no longer give offense. Constant care and supervision are necessary.

Some stokers are more efficient as smoke preventers and require more care in operation than others, while, as has already been mentioned, certain stokers are better adapted to some conditions than others. Intelligence is more necessary in handling a stoker than in a hand-fired plant, if good results are to be expected.

Steam jet devices while usually installed to work automatically require constant care and attention. A great deal of criticism has been directed against these devices on the ground that they are costly to operate and liable to get out of order. With proper care they do and can give efficient service for many years.

It is necessary for public officials to be very careful in recommending this or that device. We do not, however, hesitate in plants which are new, or just being equipped, to recommend the installation of mechanical stokers, especially if there are

several boilers in the plant. In other cases where the boilers are old, or few in number, and likely to be soon replaced by new, it would seem to be too great a hardship to require the purchase of stokers. In such instances, the remedy is sought in the use of steam and air jets.

It is a well-known fact that if a person once has a bad name that reputation will always cling to him. Cleveland has had the name of being a smoky city, and, while a great deal has been accomplished in the way of smoke abatement, I frequently meet people who scarcely realize that anything at all has been done. As a matter of fact, however, I think I am safe in saying that the sum spent in Cleveland in the last seven years will run pretty well up into the millions. Take, for example, one company, namely, the American Steel & Wire Co. About six years ago they were prevailed upon to equip one of their plants with mechanical stokers. Today they have over 100 boilers equipped with chain grate stokers and these 100 boilers have taken the place of about 200 old boilers. The expense of installing stokers hardly justified the use of the old boilers, consequently new boilers of larger units were installed in their place. In order to get the full benefit of the new equipment it was necessary to install an overhead coal bin with automatic coal conveyors and this again made it necessary in most cases to put up new buildings. In the case of one plant, the Consolidated Mill, 24 boilers were replaced by 16 new water tube boilers, a new building and two new stacks in place of 24 stacks as was formerly the case. These stacks are 200 feet high and are a striking example of what can be done in the way of smoke abatement, being absolutely clean at all times. This is only an illustration of what has been going on in all parts of Cleveland since the department first began its work.

Believing thoroughly in education rather than coercion, our method in brief has been this: First, a visit to obtain data for our index of boilers and furnaces; next a series of 100 readings of the chimney at various times to determine the smoke average copies of the average for each locality being mailed to the firms interested accompanied by letters of criticism or of

commendation. Finally personal visits to the manufacturer in an endeavor to make him see the matter as we see it. Some responded instantly and were only waiting to be asked, others put off and asked for time, but nearly all have been courteous and ready to consider the subject. The feeling is well developed among business men and manufacturers that smoke is a positive evil and that it is possible to abate it.

A canvass of the city shortly after the department began its work showed something like a total of 2,000 boilers, of which about 400 were equipped with devices of some kind or description for the prevention of smoke. The records of the department at this time show a total of about 2,800 boilers with about 2,000 equipped with means for smoke prevention. A brief summary of the various kinds of equipment may be of interest to you:

Chain grate stokers	225	boilers
Inclined grates	450	"
Underfeed stokers	180	"
Automatic steam and air jets	550	"
Various devices, gas, etc.	50	"
Hawley down-draft furnace	50	"
Smokeless coal	500	"

These figures are approximate, but will serve to give you an idea of the different methods adopted.

At the time the ordinance creating the department was passed, the term of office for the smoke inspector was made five years. The city administration changes every two years and it was decided that this time was hardly sufficient to permit of any effective work being done. The wisdom of this provision is apparent to all who are familiar with the difficulties attendant upon a campaign of this kind.

Our department acts as an information bureau both for manufacturers considering new equipment as well as for firms who are seeking to introduce their devices. We have a complete record of the number and style of boilers in each plant, together with such other information as may have a bearing on the subject. We have the support of the Chamber of Com-

merce and the Builders' Exchange, both of which have appointed committees to act in an advisory capacity with the smoke inspector.

We have on file in our office several hundred letters from manufacturers testifying to a saving in fuel as well as a saving in labor effected by the installation of the various devices. These letters are evidence that while the most of these were installed for the purpose of abating smoke, the results have shown them to be beneficial to the plant owners from a financial standpoint.

An extract from one of these letters will give a fair idea of what this saving amounts to: "We were very loth to install stokers here; we did not believe that they would do all that was claimed for them, but after a very careful investigation, and we might add that our investigation was inspired by the possibility of being subjected to annoyance through legal process by your department, we installed the Jones Automatic Stokers under our four boilers, and we are highly pleased with the result obtained. It is nothing short of blindness for any concern which generates their own power, not to install some automatic device for the burning of their fuel. Under the old system of hand firing we burned from 18 to 22 tons of coal per day, consumption varying with the quality of coal used, and it was frequently necessary for us to have two firemen and a coal passer to take care of three boilers. The coal cost us from $1.90 to $2.25 per ton, according to the supply and demand, and the results were anything but satisfactory. It is necessary for us at our plant to carry between 95 and 100 pounds of steam constantly, because on our steam pressure depends the capacity of our pumps to relieve our condensers of water, and a variation of five pounds in our steam pressure completely deranges our evaporating apparatus. Since we have installed our stokers we are using coal costing from 50 to 75 cents a ton less, and the results are decidedly better and our steam never varies over two or three pounds, and we are burning about six tons of coal per day less than under the old system of hand firing. It appeals to the writer that a system

of automatic firing is preferable to hand firing, aside from an economical fuel consumption, as a more uniform head of steam is possible." This letter speaks of the economy effected.

The following deals more with the results from the standpoint of a clean stack: "I write to ask your suggestions in regard to a chimney which we built two years ago, which we have been using for the past year. I believe the general impression is that chimneys are used for the purpose of carrying away smoke, but this new one that we have been using for the past year does not seem to fill the bill in any sense, for it not only does not carry away smoke, but the bricks at the top even are nearly as clean and free from grime as when it was first erected. Should you happen to be out in this neighborhood I would be glad to have you call and give us any suggestions which your experience may lead you to offer looking toward the proper utilization of this chimney. The furnace under it is developing at least 350 H. P., and the coal we are using is the cheapest kind of slack. We have, however, thus far been unable to make any smoke. Can you tell us what is the matter?"

One great difficulty which has been encountered in our work has been the disposition on the part of owners to feel that their responsibility ended with the installing of some device. It has been our aim to impress upon the manufacturers the importance of making it their personal business to see that the best results are obtained at all times. Where this is done, we invariably get good work. As an instance of this, one of our plants includes four boilers with four stacks, of which never more than three are in operation. The owner's instructions to his engineer are that this plant must be operated at all times so that any person observing the top of the stack will be unable to tell which boilers are in commission. Another manufacturer gave his engineer full authority to select new boiler and stoker equipment for his plant with the proviso that after the same was installed he would hold him responsible for

any smoke. We have never seen this plant smoke since it was installed.

Smoke from locomotives constitutes a large share of the city's smoke. Locomotive stacks are low and the smoke is usually carried into homes and offices before it is diffused through the atmosphere. While a number of devices have been advanced to bring about a reduction of this smoke, none of these have been finally adopted by any of the railroads. There was a time when the fireman fired entirely by the stack, and as soon as the smoke ceased to roll out of the stack it was a signal for putting in more coal. There was no thought of reducing smoke; in fact, it was considered a necessity. This is no longer true and railroad officials are anxious to co-operate with city officials in an effort to bring about an improvement in conditions.

When we first began our work in Cleveland, an inspector was detailed to take observations of locomotives. He stationed himself at a convenient point where an engine could be observed for a period of three to five minutes. Observations were taken every five seconds and conditions as to load and style of work, whether passenger, freight or switching were noted. The percentage of smoke was then determined and at the end of the day copies of the cards taken were sent to the officials in charge of the crews, usually the road foreman of engines. Attention was called to cards showing unnecessary smoke, and in most cases this resulted in the crew being reprimanded for their carelessness. If the same crew offended several times it meant suspension of anywhere from one day to two weeks. The first month these observations were taken the average amount of smoke for each engine was 30%. The average emission of smoke for each engine during the year 1907 was about 4%, showing that the constant agitation of this subject among the men has brought about good results.

Not all of this improvement can be attributed to the improved methods of firing, however. About two years ago at a meeting of the superintendents of the various roads, called by the smoke inspector, they were notified that some further

steps must be taken to reduce the smoke from locomotives. After considerable discussion a committee was appointed to make some investigations. This committee finally recommended the adoption of a steam jet device which has since been installed on all the switch engines in the city. This device consisted of several steam impelled air jets entering either from the front on each side of the fire-door, or from the sides of the firebox. An adjustable damper in the door provides additional air when necessary. A hollow ring with a number of steam jets for discharging steam upwards into the stack is used to furnish draught when the engine is standing. With the aid of this device and light firing it is entirely possible to abate almost all of the smoke. Several tests made showed that where the firing consisted of two or three scoops of coal and the jets used, the stack never showed as high as 20% of smoke, and this only for five or ten seconds. Of course, care and intelligence are just as necessary in this as in the case of stationary plants, and unless the device is used no results can be obtained.

Our greatest difficulty in the case of locomotive smoke is due to the large number of new firemen constantly being employed. To overcome this difficulty, men have been designated by the railroads to instruct these new firemen in the correct method of firing and they also act in the capacity of smoke inspectors.

The unanimous opinion of the smoke inspectors attending the meeting in Milwaukee last summer was to the effect that the responsibility be put upon the stoker company for installing their devices in such a way as to fully meet the requirements of the ordinance with reference to smoke abatement. It should be their duty to study the conditions of the plant and satisfy themselves that they are such as to insure the best results being obtained.

It sometimes happens that after stokers are installed the stack still continues to show considerable smoke, due possibly to lack of draught, or some other cause, which should have received attention at the time arrangements were made to install

the devices. As the authorities become more insistent in their demands for a smokeless condition of chimneys the owners are apt to become more exacting in compelling strict compliance with the terms of the contract calling for smokeless operation of the plant. At the present time it is not unusual for contracts for stoker equipment to provide that the elimination of smoke must be sufficient to conform with the city ordinances and that the approval of the smoke inspector must be obtained before the same is accepted. It is my opinion that the stoker companies are fully awake to this situation and are making every effort to bring their devices up to the highest state of efficiency.

The use of central heating plants appears to be constantly growing in favor. The distribution of heat from a well equipped plant is one of the most effective ways of cleaning up a large number of small heating plants. These plants are usually situated in business districts in old buildings where the conditions of draught and other equipment make it impossible to apply any of the modern devices for abating smoke. In these days of sky scrapers it is not unusual for the top of the stack of an old building to be so situated that every time the stack smokes it is blown directly into the windows of some high office building. It has been our policy in such cases to have the owners of the offending building take service from one of the larger buildings in order that the small plant might be shut down.

Several years ago the smoke inspector called a meeting of a number of business men located in a certain district and suggested the advisability of building and operating a central plant to furnish light and heat to all the buildings located in that territory. The plan called for a co-operative plant and was very favorably received, but the old saying, "Many men of many minds," was once more exemplified and after considerable discussion nothing was done. Since then this proposition has been taken up by private parties and carried to completion and today this plant is serving between 15 and 20 buildings. Some of these buildings were chronic offenders and the improvement

in this district is very noticeable. I might say further that this concern is now applying for a general franchise to supply the whole business district with light and heat.

The increased use of gas engines will undoubtedly be the means of reducing a large percentage of the smoke that we now have. The extension of lines from the natural gas belt have given an extra incentive to the use of this method of generating power, and the economical results obtained by those who have installed them will induce others to make like changes. A number of boilers are being equipped to burn natural gas and the convenience and the cleanliness of this kind of fuel are strong arguments in its favor. The uncertainty of the supply of this fuel has undoubtedly kept it from coming into more general use, but the idea frequently suggested of manufacturing gas and electric power at the mines and either piping or transmitting it direct to large cities conveniently located may eventually be carried out and may result in the furnishing of cheaper power and at the same time cleaning up the atmosphere of the cities so favored.

A great deal of experimental work has been done by the government under the direction of the Geological Survey. A number of valuable books have already been issued and another one is now in the hands of the printer which will be issued shortly. This book will give a description of a large number of smokeless plants and contains a vast amount of information which has been gathered by representatives of the government in almost all of the large cities where bituminous coal is used for fuel. These books are intended for general distribution and can be had by applying to Professor D. T. Randall, engineer in charge of smoke investigations, care of the Geological Survey.

In conclusion, I wish to say that at no time in the past has the outlook been so favorable for a solution of this perplexing problem, and the most hopeful sign of the times is the strong public sentiment which is demanding the abatement of smoke.

DISCUSSION.

Mr. Wm. H. Rea: I would like to ask how long this work has been under way in Cleveland, and also what has been done in reference to abating the smoke from boats? They claim they are on government property and are exempt.

Mr. Krause: We have been engaged in this work for seven years, but have not done very much with the boats on account of the question of jurisdiction. A decision was rendered on this question during the past year in Detroit, in a bitterly contested case involving one of the railroad transports crossing the river between Windsor and Detroit. We have, on the lakes, a number of boats equipped with mechanical stokers and the engineers of some of these boats testified to their efficiency and economy of operation. The court held, however, that while the smoke inspector of the city of Detroit had jurisdiction over the river, no device, practical in that class of service, had yet been invented. This service is very different from stationary or locomotive work. The boats may drift along for a time, then work to their utmost capacity for a few minutes and then drift again for ten or fifteen minutes. The demand for steam changes so suddenly from the full power of the boilers to the opposite extreme, that an automatic coal feeding device is almost out of the question.

Chairman: We would like to have Mr. Rea tell us something about the work of the Pittsburgh Smoke Inspection Bureau.

Mr. Rea: Our experience has been very pleasant so far, and we have not had a single refusal to comply with the requests that we have made, some of the smoke producers acquiescing a great deal more readily than others. We have taken the stand that we would not tell them what to buy, or recommend any particular apparatus, because that would make the city responsible for the working of the device, and create an impression that we had an interest in making specific recommendations. I think boilers have been built more for the purpose of getting an overload out of them when necessary

rather than with a view to the consumption of smoke, and if people demand and specify a smokeless plant the boilers will be built with proper furnaces and stokers to comply with that demand.

We have only been in operation since the 12th of June and since that date smoke consuming devices of various kinds have been installed in about ninety-eight different plants, these including mechanical stokers, steam jets or special furnaces. Results are not very apparent yet and it will take time to show appreciable improvement, particularly on the North Side. We commenced work there the 3rd day of the present month. Much of the smoke in the lower part of town is due to the rolling mills in the North and South Sides of the city. One large concern on the North Side, and a very bad smoker, asked us for a copy of the ordinance and they expect to comply with it, although that means an entire rebuilding of their plant and an expenditure of anywhere from $50,000 to $150,000.

Mr. Wilson: I have been interested in smoke prevention for the past ten or fifteen years. Pittsburgh had a smoke ordinance long before the present one was enacted and it accomplished about as much as was expected of it, until the matter was taken into court and we found it would not stand. I doubt very much if the present ordinance will stand if any person wants to fight it. I do not think we are taking up the matter in the proper way, when we attempt to specify what is meant by light gray and dark gray smoke. That is a matter of opinion. The question of smoke prevention should be put in the same class as building and boiler inspection. By way of illustration, the erection of a frame building in the business part of the city is not permitted, and it seems to me that a steam plant should similarly be governed by proper restrictions. The work should be placed in charge of a competent official to see that there is ample boiler capacity, proper devices for the prevention of smoke, correct design throughout, and, like the boiler inspector, let the official inspect the plant and say whether it should be operated.

I do not believe that any plan which attempts to do away with smoke all at once can be effected, because the larger manufacturing plants will not stand for it. The amount of smoke a man makes is something of a nuisance to him, but nothing in comparison with the cost of changing his plant.

Mr. Krause: We are contemplating something along those lines in Cleveland. Within the last three or four months the smoke and boiler inspection departments have been combined with the building department. Unfortunately we have no authority to inspect boilers under our state law and the municipality has no authority to legislate on the subject, but there will probably be such a law introduced in the legislature which is now in session. We have, however, an ordinance which provides that any person installing or altering a steam boiler must receive a permit from our office, and he must file a written statement describing the methods he intends to employ for the prevention of smoke. But if we could go further and compel him to submit his plans, and if the city had authority to alter or change the plans, it would be a long step in the way of the ultimate solution of the problem. They have such a plan in force in Chicago, and I think sooner or later you will have to come to it in Pennsylvania. I have read your smoke ordinance and I think you have probably as good an ordinance as any city in the United States. It seems to be reasonable, fair and definite.

Mr. Wilson: I was very intimately connected with the case in which our last smoke ordinance was declared invalid, and after going through the inferior and superior courts with that case, I do not see how anything can be accomplished by means of an ordinance employing such indefinite terms as gray smoke or dark smoke. To distinguish the one from the other is purely a matter of judgment, and a prosecution can not be conducted on personal opinion.

Mr. Krause: These cases are usually decided on precedent. The Supreme Court of Minnesota has stated that the term "dense smoke" conveys to them precisely the same meaning

that it does to anybody else who has ever seen a dense column of smoke coming from a stack.

Mr. Wilson: In the case of the City of Pittsburgh vs. W. H. Keech, to which I just referred, the ordinance declared that more than 20% of smoke was a nuisance. No person had any idea of what was meant by the term, 20% of smoke. It was a matter of judgment. So it would be a matter of judgment as to what is light or dark gray. There must be a standard.

Mr. Krause: Personally I am not so much in favor of the Ringleman chart. I would rather have a card such as you have in some books on smoke prevention, various shades of smoke coming out of the stack and designated as 1, 2, 3, 4 and 5; look at the stack and compare that with the chart or with some chart which is set off at 100 feet.

Mr. C. B. Albree: It seems to me that the use of the Ringleman charts, or graduated cards, or any standard of a similar nature must be very impracticable and uncertain, for the reason that the intensity of light varies inversely as the square of the distance, the reverse of which is also true. In a sketch, an object in the foreground, very much lighter than something in the background, will appear very black, apparently, against the object farther away. Similarly, the shaded side of a tree standing in the sunlight in the foreground, would appear darker than the mouth of a distant cave, which is absolutely black, but appears to be lighter on account of the distance and intervening haze.

Mr. Schellenberg: Last year we were shown, by Mr. Mullenhoff, a German device for comparing absolutely the color of the smoke. It consisted of a piece of card board about three inches in diameter with a hole in the center and divided into ten sectors ranging from white to black. By holding it off and looking through the hole, the tint of the smoke could be compared with the shaded sectors and its density definitely designated by the standard on the card which ranged in tenths from white to black.

Mr. W. C. Hawley: Just prior to the World's Fair in Chicago, during a general cleaning up of the city, the smoke in-

spection department used photographs made in the presence of two or three witnesses. Suit was brought and the defender invariably fined, probably $50 and costs, with the promise of repetition of the penalty in two weeks, if by that time active steps had not been taken to abate the nuisance. It is only fair to say that this was done only after reasonable effort had been made to secure compliance with the ordinance and it was only in cases of obstinacy that the matter was taken into court.

Mr. Moore: I would like to ask whether it is the design to make laws for future installations without considering those already installed and in use.

Mr. Krause: Yes, for instance you now enforce certain requirements here in Pittsburgh as to fire limits, providing that on and after a certain date no building shall be erected within those limits unless constructed of fire proof material. I think the same principle would hold good in regard to the building of new boiler plants.

I have tried to show in my paper that a campaign of education will do much good. Little has been accomplished in cities where entire reliance has been placed on legal prosecutions, but in almost every case where the campaign has been carried on along lines of education and moral suasion, the work has gone steadily forward and progress has been made.

One of our large iron manufacturers told me one day that he would spend $50,000 to kill the ordinance. We suggested a meeting between the parties and their attorneys and talk the matter over, and before we got through his attorney advised him to equip his plant. If we had arrested that man he probably would have fought.

Mr. Wilson: Do I understand that the idea is to never bring it up to a test?

Mr. Krause: We have threatened to take a great many cases to court and we were ready to do it, but in every case when the time came we did not have to go into court. We give a man plenty of time, and talk to him, so that when we do finally take action, he feels guilty and takes steps to abate the

nuisance. I believe you should use discretion and not be too radical.

Mr. Rea: If there are 10% of the smokers in Pittsburgh who will not do anything (we have not discovered any yet) and 90% who are willing to put in smoke consuming devices, it is better policy to assist the 90% to take the desired step, rather than to begin the work by entering suit against the 10%, which would only delay the matter indefinitely.

In regard to large corporations, it is only fair to say that we find them favorable to our plans. One very large company in the city has 168 boilers. They have spent much time and have gone to a great deal of trouble, have sent men away to look up different devices, and have tried four or five different devices on their old boilers, with a view to installing the best thing they can find under those boilers until they are substituted by a new plant, constructed properly, and smokeless. (The speaker mentioned other large corporations and told what they are doing.) So I could run down the list of most of the large plants.

Gerald E. Flanagan: It would seem that the Cleveland policy, if I may so term it, of accomplishing as much as possible in the line of smoke abatement without plunging into a legal fight, is good and it is self-evident that it has produced some results. It occurs to me that if legal proceedings are not resorted to until after several years of productive activity, the position of the smoke abatement people is very much strengthened by that experience. If a prosecution was started before anything whatever had been accomplished, the courts would probably deem it unfair to the owners of plants to compel them to go to great expense installing apparatus which had not yet been put to a practical test.

Before the Mechanical Section, February 4th, 1908.

Chairman G. E. Flanagan

Presiding.

THE GAS ENGINE'S PROBABLE FUTURE.

By Sumner B. Ely,*

Retiring Chairman.

In trying to forecast how far the gas engine is likely to displace the steam engine, no treatment of apparatus is attempted, merely the detail specific reasons for the general conclusions reached.

Up to the present time, in this country, little attention has been paid to the invention or improvement of fuel savers. Have not the compound and triple expansion engines received most of their perfecting abroad?

We are primarly inventors of labor-saving machinery and this is, of course, to be expected, for a new country like our own has a scarcity of labor and often an abundance of fuel. It is only within a comparatively few years that we have given fuel much consideration. A very excellent illustration of this is the way natural gas has been wasted and thrown away.

It is very logical, therefore, to find the gas engine being perfected in Germany and other European countries where fuel is scarce and of high cost and labor cheap. It is true that there have been a large number of gas engines built in this country for a great number of years back, but they have been generally confined to small unit sizes and their application has been much limited by the restricted conditions under which they would operate. And while these have had good success under certain conditions, it cannot be said that they have so far been likely to displace the steam engine. It is, therefore, necessary for us to turn to Europe, and especially to Germany,

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to find out what has really been accomplished in this field. The development in the last few years has been very rapid.

At Differdingen can be seen gas engines direct connected to blowing cylinders and others to electric generators. These are in units of 800 H. P. and 1000 H. P. Blast furnace gas is used in the engines and cleaned of dust by means of fans and scrubbers. It is not uncommon to see installations in Germany of this kind at the large blast furnace plants. At one plant I recollect seeing a machine of the Oechelhauser design of 30x40 in. cylinder connected to a blowing cylinder of 72x40 in. This is merely to convey the idea that many good-sized gas engines are running successfully with no more breakage or stoppage than a steam plant. A number of American engine companies have lately obtained the rights to exploit and manufacture some of the most successful foreign designs. The large gas engine plant of the Lackawanna Steel Co., at Buffalo, N. Y., is now running and some other large installations are under construction. The gas engines at the Lackawanna Steel Co. use blast furnace gas and drive both electric generators and blowing cylinders. I understand something like 40,000 H. P. has now been installed, as I saw the plant before completion.

The fuel saving a gas engine will effect over the steam engine is well known. We all appreciate its high mathematical heat efficiency, also that the cooling water, used to keep down excessive temperatures that would otherwise prevent proper mechanical working, carries away so much heat that this high efficiency is nearly cut in half. Furthermore, useful heat is thrown away in the exhaust so that an engine in practice develops perhaps 25% efficiency. While many tests show much more than this, 25% is probably a conservative figure that can be obtained in practice. It must always be remembered that a gas engine gives its maximum efficiency only when carrying full load and that the efficiency falls off as the load is decreased. For a comparison with the gas engine, it is doubtful if a compound condensing steam engine will do

better than 12% or 13% efficiency. A boiler with its furnace that gives 70% is a very good one and combining this with the steam engine we have a total efficiency of less than 10% against the gas engine's of 25%.

The above case is applicable to blast furnace work, where the common practice is now to burn the blast furnace gas under steam boilers; or it is a comparison where natural gas is used.

If, however, the gas for the gas engine is generated from coal in a gas producer, then the efficiency of the gas producer must be taken into account.

Taking all of the above efficiencies into consideration and also the load factor, we may perhaps say of the average case met with in practice, that about one-half less fuel will be required by the gas than by the steam engine.

Some articles have been published stating that the gas engine on blast furnace gas would use for the same work only 1/5 or 1/6 of the gas required by steam boiler and engine. Most of these articles are based either on calculated results or exceptional tests, and the conservative engineer will be doubtful of such enormous savings working day after day in actual practice.

Let us now turn to the disadvantages of the gas engine. One of the most serious is its inflexibility regarding overloading. As already stated, the maximum efficiency is at maximum load and consequently to get the economy, the builders have generally in the past sold an engine which would just about carry the load with practically no margin of power left. In most shops, particularly with the smaller engines, there is always a tendency to add more and more load from time to time as new machinery is added or extensions are built. A steam engine, if necessary, can take steam full stroke and its power greatly increased. To be sure, its efficiency falls off, but naturally the purchaser will consider excess power of far more convenience if not of actual value. He does not care to buy a new engine every time he belts a few more machines onto his shafting.

The maximum load consideration always comes up in the case of varying loads. For instance, after designing as heavy and large fly wheels as practicable, suppose that we will need 700 H. P. the greater part of the time, but occasionally as high as 1000 H. P. will be needed. A steam engine rated at 700 H. P. if overloaded 38%, viz. to 1000 H. P., would not show much falling off of efficiency. A gas engine to give a good efficiency should not carry less than 80 or 85% of its maximum capacity. This would mean we would have to install a gas engine of at least 800 H. P., or better still, 850 H. P.

A great many figures have lately been published including load factor, interest on investment, depreciation, etc., etc., but without going into this, suffice it to say that with coal costing about $2.00 per ton or more, a resultant saving (except in exceptional cases) can be shown in favor of the gas engine, this being more or less depending on the many conditions which always enter the problem.

As already stated, in the average case the gas engine shows about one-half the consumption of the steam engine.

Before leaving this point, it is interesting to note in some of the foreign installations, how, in blowing cylinders connected to gas engines, the air pressure is increased. Suppose a gas engine is designed to give an air pressure of 20 ℔s. per square inch when working at full capacity, and now suppose we desire a pressure of 30 ℔s. to help out the working of a blast furnace. We might have installed an engine which would give 20 ℔s. when working at, say, half its full load, but not only would this be expensive in gas consumption but also in first cost of installation.

The method referred to provides the blowing cylinder with a valve, arranged so that when excess pressure is wanted this valve allows the piston to pump into the atmosphere for the first portion of the stroke. It then closes, and the extra speed and impetus which the piston has gained brings up the pressure.

Of course, the volume and weight of air pumped falls off,

but it is stated that double the normal pressure can be obtained in this way.

The difficulty of reversing a gas engine is often advanced against it, but with the many satisfactory clutches, both for very large and small work, this objection does not mean much.

I want to speak now of what, to my mind, is really the key to the general use of gas engines, and that is the production of a proper gas for the engine to run on. Experience shows that gas engines can be designed (not that all are) which will run successfully from a mechanical standpoint, experience also shows that blast furnace gas can be cleaned successfully, also that natural gas can be used, also that gas can be made from coke or anthracite coal, but it has not shown that we have an altogether satisfactory gas producer for bituminous coal, and until such is put on the market it is hard to see how the general adoption of gas engines can take place. Bituminous coal is our great commercial fuel and the universally accepted engine must run on it.

It is not an easy matter to get a gas from bituminous coal which is clean. For gas engine work, if much dirt is present, it cakes and bakes on the cylinder walls, becomes incandescent and explodes the charge at the wrong time. There are, however, one or two makes of producers that come very near being generally satisfactory, but are complicated by washing and cleaning apparatus, and to obtain economy it is often necessary to sell a bi-product. Installations for small plants are hardly expedient.

There is, however, at present, considerable experimental work going on, and I for one believe it will not be many years before we see gas engines producing a brake H. P. per pound of bituminous slack coal, from a simple and efficient gas producer.

To sum up the previous remarks, to my mind before the gas engine can come into very general use we must first have a simple and satisfactory bituminous gas producer. Granting that this will probably come, the gas engine still for general use is hampered by its inability to carry overloads. However,

as time goes on and the price of fuel goes up, as it must, due to the economic law of supply and demand, we may expect a good many gas engines to replace steam. First, however, before economy the general user appreciates the flexibility of the steam engine, and I cannot believe the gas engine will ever entirely displace the steam engine. The gas engine will fit into certain conditions and places admirably and its field will undoubtedly be enormously increased with the advent of high-priced fuel and a proper gas producer.

DISCUSSION.

Mr. Hardie: Relating to Mr. Ely's reference to the non-success of bituminous gas producers when applied to power development or the driving of gas engines, would remark that, while such may be the case in connection with comparatively small installations of the suction type, in large installations operating for power only, or for power and fuel purposes combined, highly satisfactory results have been obtained from bituminous coal.

On the continent of Europe and in Great Britain, large and numerous installations of this class are in successful operation, meeting the demand of central power stations and the various requirements of the metallurgical and manufacturing industries, included in which is the operation of large unit gas engines. In connection with these operations, however, very important economies are effected from recovering, in the form of sulphate, the ammonia originally contained in the coal. Throughout England and Scotland such well-known firms as Armstrong, Whitworth & Co., Vickers, Son & Maxim, John Brown & Co., and the Wm. Beardmore Co., severally engaged in the steel manufacturing business, operate extensively, and in some cases entirely, by Duff recovery plants adapted for genrating gas from bituminous coal, using the gas for the melting and heating of steel, and after cleansing, in the gas engines operating throughout the works. It should be of interest to note that Mr. Beardmore, whose company operates in steel works and shipyard an equivalent, in Duff plants, of over 100,000 h. p.,

stated, in the course of a speech made after the recent launching of a battleship, that this yard was unique in that no steam is used as a motive power, internal combustion engines being used to generate electric power to operate the motor driven machines throughout the works. He further stated that from the gas used for power purposes enough sulphate of ammonia was recovered to pay their entire coal bill.

Mr. Stucki: Some time ago I had occasion to look into the question of installing a producer plant, and found that in a large size by-product plant, the cost of the coal at about $1.50 per ton, will be entirely offset by the by-products, and this is said to hold true for installations of not less than 75 to 90 tons per day of 24 hours.

To abstract the tar, which is the most difficult operation in cleaning gas for power purposes, several methods are employed. The U. S. government, during the St. Louis Exposition, made exhaustive experiments with producers, and used the mechanical or centrifugal washer, which precipitates the tar against the periphery of a rotating housing, and from which it is afterwards washed out. This device is much used in Europe, but it is somewhat bulky.

Another method consists of an inverted producer, which has lately been perfected to such an extent that it is now offered to the trade. It now appears that the principal difficulty in the use of bituminous coal for gas engine purposes, the elimination of the tar, has been successfully overcome.

The economy of gas power is forcibly illustrated by the fact that gas engine installations are now sold under a guaranteed fuel rate of one pound of coal per horse power hour, while a high speed steam engine plant consumes 3½ pounds, and a triple expansion engine, 2.3 pounds.

Mr. Hardie: Conditions naturally depend to great extent on the prices governing the sulphate of ammonia and coal, also, in the yield of ammonia from the coal gasified.

With a consumption of 90 tons per day, however, of coal costing $1.50 to $1.60 per ton, and containing not less than 1.3% nitrogen, and with sulphate of ammonia selling at $60.00 per

ton, the returns from this by-product alone should be sufficient to reduce the ultimate cost of the coal to approximately 20 to 30 cents a ton.

Mr. Ely: The case illustrated in the paper was 700 h. p. loaded to 1000 h. p. That is not at all an excessive overload. An overload of from 700 h. p. to 1400 h. p., however, is a very different proposition, and the efficiency would fall off very rapidly. It may be interesting to note that most of the centrifugal fans separating blast furnace dust from gas have to run at a very high speed, and there is danger of the fan going to pieces if the speed is not kept within safe limits. Some one has suggested a very ingenious plan consisting of a helical passage for the gas, running it through at high pressure and consequent speed. The gas swirls around and produces the same effect as the fan gives, and without the mechanical movement. It is not, however, altogether practical, and it is expensive to raise the gas to the high pressure required. The plan of running the gas down through the inverted producers always appeared to be a reasonable way of taking out the tar. I know of one plant in Germany, I think it is a double producer, where they fire one side for a time and then reverse it and fire the other, but they experience more or less trouble.

Mr. Leland: The plan of paying for the coal by the proceeds from the by-products would not hold good if the practice should become universal, for the reason that the value of the by-products would go down amazingly. The question of gas engine overload could easily be taken care of by having a plant consisting of several units, using as many of these as can be operated at full efficiency, and starting up additional engines when more power is needed.

Mr. Ely: With blowing engines, how are you going to boost your pressure?

Mr. Leland: That may be done by discharging part of the intake air into the atmosphere and compressing the remainder to the pressure desired.

Mr. Ely: Dividing into small units does not help to run up pressure for blowing. Of course a special device, such as I

have suggested, can be used, but that is not taking care of the overload by division into small units; a gas engine air pressure coefficiency depends on its cylinder diameters.

It has been suggested that producer gas is likely to be used for domestic purposes. There is one objection. There are perhaps eleven or twelve lines bringing natural gas into Pittsburgh. The heat units for producer gas are roughly about 100, while natural gas is 1000, nine or ten times as much. This being true, the amount of piping necessary would be enormous.

Mr. Leland: The use of producer gas for domestic purposes would be very dangerous. It is a most poisonous gas, which is a very serious objection to its use in the household.

Mr. Ely: The use of producer gas for domestic purposes is not an experiment. On investigation you will find it has been satisfactory in most places.

Mr. Hardie: Considering the value of by-products the sulphate of ammonia alone, for fertilizing purposes, has a steadily increasing demand and a market value of from $55.00 to $60.00 per ton. On a basis of recovering from 70 to 90 lbs. of sulphate of ammonia for each ton of coal gasified, it will be seen that high economy is contained in the recovery process. Quoting from U. S. government statistics, in the year 1905 the country produced 38,663,682 lbs. of sulphate of ammonia, and imported 30,576,558 lbs. The recovery process is extensively used in Europe, and with our incomparable resources in bituminous fuels, and in view of the practical economies elsewhere established, it would seem that we have before us a most extensive field for development.

Mr. Flint: I know, from personal observation, that in England both anthracite and producer gas are used extensively. Dowson anthracite producers are often used in small size electric light and power plants, and Mond bituminous producers are frequently installed where large amounts of power are required. The Mond producer plants furnish a gas adapted to manufacturing purposes, such as heating soldering pots and other light work, in addition to running gas engines.

I ran across a rather interesting practice in Coatbridge, Scotland, where they were using bituminous coal in their blast furnaces, and were recovering sulphate of ammonia, tar-oil and pitch from the gas. They then used the purified gas for their stoves and for running a blast furnace gas blowing machine. After separating the tar-oil and pitch they re-combined them in proper proportions to meet the demands of the trade.

Referring to gas engine overloads and efficiencies, if there be installed a gas engine which will normally run at half load and which will occasionally be called upon to develop twice that power, the engine will use 25% to 30% more gas per horse power when running on the usual half-load than when running on full load. For instance, an engine which uses gas containing 11,000 B. t. u. per b. h. p. hour at full load, should consume about 14,000 B. t. u. per b. h. p. hour on half-load, which is still good economy, but the increased first cost of such a plant is a disadvantage. This excessive cost can be avoided by putting several gas engines in a central power house whose peak load will be a much smaller per cent of the average than would be the case if each gas engine were direct connected to its mill. In such a central power plant the gas engines can be operated at or near full load most of the time by starting or shutting down units to correspond with the expected changes of load.

Speaking of the possibility of obtaining most of the power for a steel works from blast furnace gas, I would like to call attention to Deutsch Luxemburg Eisen und Hutten Actiengesellschaft, at Differdingen, which in 1905 was developing so much power in blast furnace gas engines that they only required additional fuel to the amount of 500 ℔s. of coal per ton of finished steel. They manufactured rails, structural material and wire.

Mr. Hardie: In cleaning the gas which has passed through the recovery process for use in driving internal combustion engines, no difficulty need be anticipated. In the city of Madrid, Spain, where there is a Duff recovery plant of 12,000 h. p. for the supplying of municipal light and power, one of the 2000 h. p. engines, on examination after a non-stop run ex-

tending over a period of six months' duration was found to be in a highly satisfactory condition, only requiring cleaning of the valves before re-starting. At the United Alkali Co.'s works, England, the Duff process is also in operation, chemical furnaces and gas engines are here operated, and the fact that this plant is now in its fifth year of continuous operation is probably a world's record and speaks most favorably of the success attained in the adoption of such gas for the purposes of deriving either power or heat.

Mr. Ellis: I looked up the question of gas engines to some extent in Europe the latter part of last year, and found that as far as rolling mill practice is concerned, they had one objection. They do not seem to be very satisfactory in large units if connected direct. I found that in a number of cases the shafts were small for rolling mill work and they would break.

I believe that the gas engine is the coming power for steel plant work and also for marine work. At Vickers Son & Maxim they now have a boat with a 500 h. p. gas engine driving the propeller, and it does very well indeed. I understand they are now figuring on a boat to have a gas producer and engine installation of 40,000 h. p., and they will get the same distance of travel, the same speed and the same horse power with 750 tons of coal as formerly obtained with 1100 tons. Of course an increase in speed will change these figures.

Mr. Ely: What we want is a satisfactory gas engine for steel mills. Some years ago I had occasion to compile a lot of figures on this subject and the general conclusion was about this: if you could take an ordinary blast furnace and utilize all the gas in gas engines you will still have, with the blast furnace plant only, a lot of surplus gas, to make use of which is a problem. If you have a steel mill, a gas engine may be used, but at the present time few engineers would use a gas engine in a steel mill. The gas may be turned into electricity, and the next problem is either to sell the electricity or have all the mills equipped with motors, which is quite an undertaking, considering their size and cost. In a plant consisting of blast furnaces only, it is a problem as to which is the more economi-

cal power, gas or steam. The surplus power must be disposed of to advantage, and one solution of this lies in the adoption of gas engines in the steel mills.

Mr. Lyons: Regarding the question of overload, for a plant of 700 h. p., I would suggest installing three 350 h. p. engines, operating two of them all the time at practically full load and maximum efficiency.

The time when the overload occurs is known, and to provide for the same, the third engine should be started and operated during the period of overload. The rolling mills provide an excellent opportunity for the utilization of the waste gas from the blast furnaces, by generating electricity and using it for driving the mills by electric motors.

One of the rail mills at the Edgar Thomson steel works is successfully operated by electricity, and a large plate mill of the Illinois Steel Company at Chicago is operated by electric motors. Electricity for driving the steel mills has been in use for a number of years in Germany, the development being caused by the enforced necessity for a lower cost of production.

We are all interested in the question of by-products, as it involves the welfare of the nation. In some of the states the soil has been so impoverished by continuous use and neglect to replenish its richness by fertilization, that the yield at present is only about one-fourth what it was when first cultivated.

The production of crops destroys the nitrogen in the soil. If nitrogen is recovered from the coal in the production of gas, in the form of sulphate of ammonia, it provides a very good material for enriching the soil. Nitrogen being a non-combustible gas, its removal from the gas is an advantage. On account of the economic principles involved, the subject should receive serious consideration from every patriotic citizen in an effort to assist President Roosevelt in conserving the natural resources of this great nation.

Mr. Hirsch: Supplementary to Mr. Lyons' remarks it may be interesting to note that the Indiana Steel Company at

Gary is putting in engines to be operated by blast furnace gas. When the plant is completed they will have about 100,000 h. p. for blast purposes, and for generating electric power. The Edgar Thomson plant, to which reference has been made, has three units, two blast engines and one driving an electric generator, each of the units ranging between 2000 and 2500 h. p.

The Gary plant will have a number of steam driven blowing engines to start and operate the furnaces until they generate sufficient gas to operate the gas engines.

Mr. Lyons: The internal combustion engine is as reliable as the steam turbine and the steam engine. The troubles of the internal combustion engine have been caused by mechanical defects which could only be discovered by use. No effort has been made to attack the theory or the thermal efficiency of the machine. Several very serious accidents have occurred to large steam central stations which were not reported in the public press. If the data regarding the accidents in the early years of the steam engine and the steam turbine were available, would the internal combustion engine suffer by comparison? The statement was made recently that it is not unknown for the steam turbine to be dismantled and rebuilt at the end of a week's run.

The thermal efficiency of a good gas generator at the present time is 80 per cent. The thermal efficiency of the internal combustion engine is at least 30 per cent., and some recent tests have shown 43 per cent. An assumption of 80 per cent. thermal efficiency for the generator and 30 per cent. for the engine, gives 24 per cent. thermal efficiency for the fuel, while the steam plant will give about 10 per cent. With coal having a calorific value of 12,500 B. t. u. per lb., and an internal combustion engine capable of producing a brake horse power with 10,000 B. t. u., one brake horse power can be developed from one pound of coal.

With a gas plant having a by-product apparatus for the recovery of sulphate of ammonia, it is possible to give the fuel cost a gross credit of $1.75 to $2.10 per ton of coal gasified.

Mr. Flanagan: Too much stress cannot be laid on the importance of the recovery of the by-products. There never was a time in the history of the world when the conserving of nature's resources was more important than it is to-day. While each generation is entitled to its share of the treasures stored up by nature, it has no right to destroy that which equitably belongs to the generations coming after.

M. L. J. Affelder: I would like to know how the cost of maintenance of the gas producer compares with the cost of maintenance of boilers and the amount of labor required.

Mr. Hardie: As the plants already referred to work steadily under very light and well regulated pressure the need for repairs is consequently small. It is found that, with ordinary intelligent care exercised in operating, the producers will run for long periods without further attention than that usually given such equipment at a week's end. The amount of labor required to handle a plant of this class is not excessive, nor need it be of a highly skilled quality; speaking approximately, the labor required to operate 10,000 h. p. installation with recovery process will amount to $40 or $50 per day of 24 hours, exclusive of any attendance for gas engines.
gines.

Mr. Ellis: In the Gary mills most of the drive will be motors. In the rail mill they have several 6000 h. p. motors and three or four 2400 h. p. motors, some 600 h. p. and numerous others of all sizes. The universal mill at South Chicago has been running successfully since about August, and it shows the advantage of the motors over the reciprocating engine, in that there is freedom from shock. That 2500 h. p. motor reverses in something like $\frac{3}{10}$ of a second, as near as I could time it with a split second watch, and it reverses from full speed to full speed in four seconds. There is a very large fly wheel running continuously in one direction at about 120 revolutions a minute.

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REGULAR MEETING,

February 18th, 1908.

President J. K. Lyons

In the Chair.

HEAT TREATMENT OF STEEL RAILS.

By William Metcalf,

Past President.

All I can say about the conditions involved in the making of good rails has been published over and over again, and everything I have to say tonight in regard to the properties of steel and the application of them to the making of rails has been published in the first paper read before this Society, (and which I had the honor to read), on the subject, "Why Does Steel Harden?" I was surprised to find that I had gone into that subject so completely that there is really nothing more to write now. That paper may be found in our annals, and it also appears in a little book, "Treatment of Steel," which the Crucible Steel Co. has published. Therefore, there does not seem to be any good reason for elaborating that subject tonight.

The importance of making good safe steel rails, capable of withstanding the service to which they are subjected, cannot be exaggerated, whether considered from the standpoint of the

economical operation of railways, the immense capital involved in rail manufacture, or, more particularly, the safety of the public travelling over the country at the rate of fifty, sixty or even eighty miles an hour. The question then is, "How to make the rails safe?" I am here this evening to try to show; first, the principles and processes involved in the handling of steel; and second, the proper application of those principles. As I said before, the principles are all published in the first paper read before the Society and which may be found in the Proceedings, vol. I, page 5. The application of those principles, however, is another matter, but in this case very simple. The chief thing I wish to consider is the heat treatment of steel. I do not give the micrographs much credit for investigations made in heat treatment; that is the one thing which, to my certain knowledge, every steel maker has been trying to impress upon the steel users for the last fifty years. The fact that high heat will raise the grain and destroy the steel, was emphasized half a century ago, before we used chemistry, microscopy or anything else in the investigation of steel, and was a fact well known and well understood. I was trained by Charles Parkin in the art of selecting steel simply by the fracture, and after months and years of training I learned it pretty well. I remember Professor Langley once asked me how close I thought we could determine the quality of steel by this method of selection, and I told him I thought we could come within 0.1 per cent.; i. e., ten points. About that time we entered into an investigation of steel, and we had Professor Langley engage in the work with us. We had everything at our command, a laboratory, and a steel works, and we went at it thoroughly and carefully. We took twelve ingots and Professor Langley first analyzed them and found, as we expected, that the carbon agreed exactly with Mr. Parkin's marks, except in the case of two ingots which showed a difference of .004, and the chemist asked us to re-inspect those ingots. We did that very carefully and Mr. Parkin and I decided that we had been guilty of a little oversight; we both thought we could see a little difference in the grain, even for that .004; but we do not

pretend that we can come that close. The mean difference between our twelve numbers in the carbon was 0.07 per cent. No chemist can determine the relative carbon with any more certainty than can be done by inspection of the fracture by one experienced in the work, providing the steel has been properly melted and the ingot properly cast. The crystallization is so distinct that an experienced man can run over a hundred ingots in two minutes and make every determination correct. It is a study which no one will tire of, once it is undertaken. I was making some experiments once, with Professor Langley, studying the changes due to very slight changes in temperature, and after working for two or three hours he looked around and said, "This acts as if it were alive." I replied, "I believe it is alive, to a certain extent." Any growth is a form of life and this is a growth of crystals.

Many people have wondered that we have not attempted to give some specific instructions about these fractures, but that cannot be done; one must see the work in order to learn how to do it. We have printed photographs of fractures but they show very little, and after seeing them one knows but little more than before. It is the same with the micrographs, and I frankly say that I place but little value in them. A micrograph three inches in diameter is a photograph, magnified three hundred diameters, of a piece of steel or rather that area of it contained in a circle .01 in. in diameter. I don't know how any one can learn anything from that, although I freely admit that they do show many of the wonderful changes that occur in steel due to variations of heat.

We then drilled those twelve ingots and determined the specific gravity of the metal. That varied with the iron, the lowest carbon was the heaviest steel, and the highest carbon was the lightest. The other elements, silicon, sulphur, etc., were practically uniform in all of them, showing that the difference in the specific gravity was clearly due to the difference in the carbon. We then rolled those twelve ingots down to ¾ inch bars, and again determined the specific gravity, using

pieces cut from the bars; this we then found, was very much greater than it was in any of the ingots, and they were all nearly the same. That showed us a fact that is well established; i. e., hot rolling and hot working condense iron.

We then annealed these same pieces and found that the specific gravity varied in the same relation as it did in the ingots; not the same in values, for they were heavier, but in the same relation. The only reason I can give (and it is given in the paper referred to), why the lighter ingots came out in the finished bar nearly as heavy as the heaviest ingot, is that the higher carbon steel was very much harder and required far more pressure to work it, which extra work increased the density. Then, in annealing them, they expanded in proportion to the quantity of carbon; the higher carbon expanded more and was, therefore, less in specific gravity than the lower carbon.

We then nicked the two extreme and four intermediate bars at about ¾ in. intervals, heated them until the end scintillated, and with a nearly constantly decreasing temperature in each succeeding section, quenched them in water and again determined their specific gravity. Then we met a surprise. In the higher carbon which was 1.079, the difference in specific gravity between the No. 6 section, which was not hot nor even colored, and the end section which scintillated, was .135. When we came down to the low carbon, which was .302, the difference was .026; in other words, in heating up from the cold bar to the scintillating temperature the highest steel had expanded, as measured by specific gravity, about three times as much as the mildest. That answered the question that had been asked. "Why is high steel so treacherous, so brittle, etc.?" If a piece of high steel be heated, it expands more, and reaches the point where it will go to pieces, sooner than a low carbon, which will not expand so much with the same amount of heat.

We then took some of those bars and verified what had been found in regard to Jones & Laughlin's cold rolled iron many years before as to specific gravity. We had tested a lot of cold rolled iron and hot rolled bars and found that in ten-

acity, hardness, resistance to compression and torsion, in all those properties there was a vast increase in strength due to cold rolling. These experiments were made in 1858 or 1859. increase in strength due to cold rolling.

Then Major Wade brought me half a dozen samples, whose specific gravity he wanted me to determine, and said they had been tested over and over again and he thought they were not right. After all the care I could use I handed him my results which, by comparing with the values he had, agreed to the third place in decimals. He said, "These three lesser values are the specific gravities of the cold rolled bars, and the greater values are the specific gravities of the hot rolled bars; I don't understand it. Here is a bar that is stronger, harder, stiffer and yet lighter." He was not satisfied, but went over to the mill and took a bar which was properly pickled and finished ready for cold rolling and measured it with very great care. They then cold rolled it, measured it again, and found that the increase in length was enough greater than the reduction in diameter to cover the difference in specific gravity; the cold rolled bar was actually larger than the hot rolled bar; in other words, cold rolling increases the volume.

Professor Langley then determined the specific gravity of four ½ in. pieces of steel taken from a bar which we hammered down cold. Two of the pieces were found to have been reduced in volume, but the other two did not show the changes we looked for. Professor Langley being dissatisfied with the results of the experiment, then boiled the pieces of steel in a solution of soda ash to make them thoroughly clean, and after quenching in water at a temperature of 60°F., again determined the specific gravity, and, to our surprise, found all of the pieces to be lighter than they were before. The cold hammered bars were lighter than the hot rolled bars, and the bars which were quenched from 212° to 60° were still lighter. We had already found that the harder the piece of steel, the lighter it was. It is perfectly plain when one thinks about it, for when it is heated the grain opens up and the steel finally melts; the hard-

ening process leaves the metal in the condition the heat produced. One of the hardened pieces of steel, of the finest and best grain, if rubbed on glass, has no effect; but the outer end, which is now so much lighter, will cut glass, but the steel will be as brittle as the glass itself. It makes no difference how little heat be added to a piece of steel, the increase in hardness due to that heat can be measured by quenching. Prof. S. P. Langley took that matter up in the Smithsonian Institution, using his wonderfully delicate electrical apparatus, and proved conclusively that steel is hardened when quenched, even from about 212° to 60° as well as when quenched from a high heat. It simply shows that heating a piece of steel enlarges it, and the process of quenching catches it in that enlarged state which it retains. If you do not quench it, but heat it to different temperatures and let it cool slowly, you will find a difference in grain due to the different temperatures, but this grain will differ from the hardened grain.

The next thing is the matter of recalescence, which we all know about. We have seen our cooling ingots suddenly get red hot. Mr. Tchernoff, the Russian, in his classical investigation, called attention to the recalescence point, the critical point; about 650°C. We know that if a piece of steel with moderately close grain be heated up progressively, as described above, a certain portion of the bar will be found to be of wonderfully fine grain. The overheated end will be very coarse, the very fine grain will be somewhere near the middle of the bar, and the other end, which was not heated, will again be coarse. The portion having the fine grain is always called the refined piece. That is the point at which all good steel makers aim. Acquiring the idea that possibly recalescence and the refining process had something in common, we rigged up a box where there was no possibility of the sunlight interfering with our eyesight, with the light dim but uniform. We had electric power, and we so arranged the wires that we could heat a piece of steel and, at the required temperature, could release it and let it drop into water. With this apparatus we proved clearly that there is

not a visible shade of difference in the color of the heat that will not make a change in the grain that is just as visible in the steel. And we found that this finest steel was secured at or about this recalescence point. If a piece of steel be heated above that temperature and allowed to cool down to that point it will not be as fine, because in cooling down slowly larger crystals will be formed due to the higher temperature. If the steel be quenched when heating up to the recalescence temperature, the grain will not be perfectly fine, but to make it so, it must not be quenched until a flash of light is seen to pass over it; it must be given time to get into the proper condition. In heating a piece of steel, just after it gets a good color, its temperature ceases to increase for quite a perceptible time; then suddenly a little light will flash over it as though a very light cloud had passed from over the sun. That is the point to catch to get perfect hardening and tempering for fine tools.

Professor Langley's explanation of this, and I believe it to be correct, is that in heating there is a tendency to break up the crystal body and when that point is reached where the crystals begin to thoroughly break up, the actual work of dissolution causes the steel to absorb heat until the breaking up of the crystals is complete, the amorphous body becoming hotter and hotter. In cooling down we have just the reverse, the crystals beginning to form, the steel gives up the heat previously absorbed, and we have recalescence.

It may seem very long to go through all this to come to the subject of rails. But the purpose is to ascertain what is going on in a piece of steel, and then to interpret and use it.

We have three terms for the grain of steel. One is called "fine," which is what we get at the recalescence point; another is "coarse," with large crystals; the third is called "fiery," because after being heated above a certain point it will become coarse, and if heated a little more it will be brilliant when it cools and will have a lustre all over it.

Now we have been taught by Mr. Parkin that every temper of steel must have a different heat to refine it. A very high

carbon steel, 140 to 150, requires a heat giving a color which is just beginning to be perceptible; a 60 carbon requires a pretty bright orange color, and a 100 carbon, the standard steel for tool purposes, a medium orange. These refined grades will come from these temperatures with a positive certainty, and we found that no matter what the carbon, the refining point was at the recalescent point.

Then there is one other feature, and it ought to be perfectly clear. If a change of temperature from 60° to 212° will make a change in the volume of a piece of steel which can be measured by its specific gravity, and if heating up produces wider and wider changes, it must be clear that a difference in temperature between any two parts of a piece of steel will necessarily produce a great strain in it. That is the reason why a steel maker will always plead for uniform heat, for otherwise he will have injurious strains. In hardening an ax, if the corners are heated up to a lemon color and the middle of the blade to a bright orange, (a man who is color blind need not try to do it), and that ax be plunged into water the corners will break off every time.

That brings us to the consideration of the rail. Now engineers tell you that basing calculations on the heaviest engines, the load on the rail is not over 11,000 lb. per unit. We all know that any steel worth anything at all will carry that indefinitely, but still the rails break. The fact is, it is not a static strain; the service produces all sorts of strains.

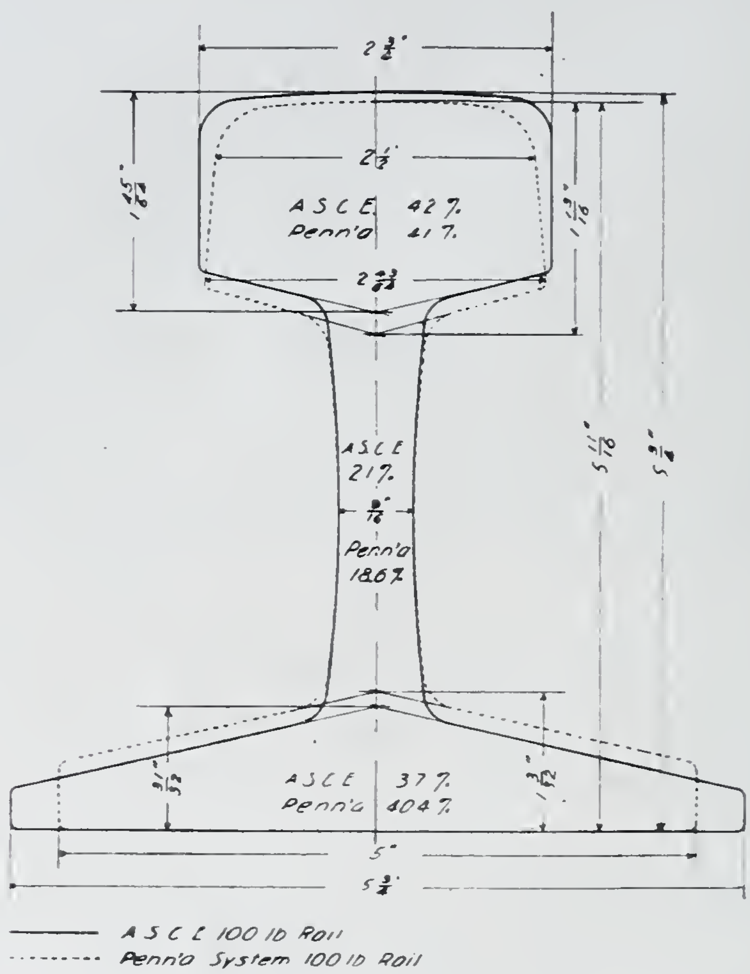
There are three kinds of breaks: There is the moon-shaped break, which is a piece broken out of the flange in the shape of a crescent, and is the commonest kind of break. Then there is what they call a split and piped head, but I do not believe that the head is piped once in a hundred times. The third break is square across, and when a rail breaks that way you will almost invariably find the grain coarse and fiery. The rail has been overheated, rolled altogether too hot, and is brittle.

Now, if railroad men want to know what kind of rails they are getting they should break them and look at

them. You can see the whole history of the rail in the fracture. An eminent man in New York said, "Perhaps Mr. Metcalf can do it but I can't." The reason he couldn't was because he didn't know how, that is, he had not been taught to do it. It will take months and years of practice to be sure of what one is doing, but the language is written there as plain as anything is written in a book; it must be made a study.

I was invited to go out to the Edgar Thomson works the other day. They had 188 rails marked for breaking. Some of them had been taken from the tops of ingots which had not been cropped, some had been cropped 5 per cent., others 10 per cent., and so on. From the very first rail they broke, the difference in the grain could be recognized from a distance of eight or ten feet. I was disappointed in those rails in one respect; it was a good deal better steel than I had expected to see come out of a bessemer converter. The steel was good where it had been rolled at the proper temperature, and when it broke, the nodules tore out. It was tough, but nevertheless it broke and it broke short. Why? On account of the internal strains. They would break in many different ways, and while they were all nicked around, one would break in the flange and another would break with a sliver two-thirds of a foot long. The rail was in such a strain that no other result could possibly follow, and such results may be expected as long as it is attempted to roll that rail. Out of the 188 rails, five were piped, and out of the five the pipe in but one ran up into the head. They afterwards put those five piped rails on the anvil, pounded them until they crushed the head right down onto the flange, and with the exception of one, they did not bend over but took the shape of that unfortunate member of the Quebec bridge; the web buckled and doubling down on itself, allowed the head to come down onto the base. None of the rails that had a little pipe in the web would split in the head, and this will give you the reason why there are so few rails that have split heads from pipe. The method of heating the rails heats them in such way

as to make the dirtiest part of the rail on top, but that is no fault of the steel. The reason they obtained this kind of grain was that when they ran the rail right through the trains without stopping, it came out so hot that it was coarse and open grained and not as strong as it ought to be. Then, in order to get the rail stronger, it was held back before the last pass until the shrinkage was limited to a certain amount; but while that was all right theoretically, holding it back in that manner, the rail went through the last pass absolutely black



on both sides of the flange, while the head was a bright orange. That crushed the grain in the flange, resulting in high internal strains; one part was a little overheated and another part underheated. I give my opinion for what it is worth; they can never roll that section (fig. 1) satisfactorily, free from strains. It might be possible in rolling this section to leave the head large when the flange is pretty nearly finished, and have a groove of such shape that all subsequent pressure would be put on the head. Whether a mechanical engineer and an in-

genious roll turner could work that out, I don't know. The Pennsylvania new section is like (fig. 2); they have taken a little weight out of the head and thickened the flange. This section cannot, of course, be made of perfectly uniform grain, but it ought to do away with much of the trouble. (Fig. 1 and fig. 2 have been combined in the engraving as the A. S. C. E. and the P. R. R. sections respectively).

Referring to split heads, the rail will have little bits of seams, but as the pressure goes over the rail they do no harm. A big ugly seam, however, will open up when the steel begins to flow as the trains pound over it, and the head is bound to split off.

One more word about rails. It has been said that they are subjected to a unit strain of only 11,000 lb. In a little book which Mr. Schoen published recently to demonstrate the value of his steel forged and rolled wheel, he describes a number of experiments to show that the wheels of a fully loaded 50-ton freight car make a measurable depression in the rail. The flowing of the top steel can be observed by looking along the rail; and if the rail is bent by weight and made to flow by pressure, 11,000 lb. is away beyond the elastic limit. Why then don't the rails break? To come back to where I started, cold rolling, cold hammering and cold drawing affects steel and makes it stronger in every direction except in the direction of the work. That is, about 75 per cent. stronger in tension, about 50 per cent. stronger in deflection and commercially very much harder.

The only conclusion that Professor Langley and I could reach concerning hardness is that it is due to tension, rigidity. If a piece of steel be heated it is opened out, and if checked there the tension will be so great that it is likely to go apart; in that condition there is nothing left to allow for ductility or flow of any kind. To my mind, I have never seen a clearer explanation.

How does this apply to rails? That tremendously heavy train, whose weight applied as a stationary load will make a little dent in the rail, when running over the rail will cause the

top steel to flow. What is the result? The rail is going through a process of cold rolling, making it harder, stronger and more rigid. It will flow a while until it reaches a point, as it gets harder, where it will not flow any longer. Cold rolling hardens and strengthens steel, makes it more rigid, and after a certain amount of flow it is hardened so deep and made so rigid that it will not flow any more.

In regard to getting rid of all these troubles, I do not think it possible to roll that rail with the thin base, with anything like a uniform grain, and necessarily there will be very bad strains in it. The new Pennsylvania section will give the roller a much better opportunity.

In conclusion I wish to say that the railroad men and manufacturers should get together. I know that railroad men are not, as a rule, foolishly exacting, and they are perhaps as reasonable a class of men as we have to deal with. On the other hand, after an experience with thousands of tons of metal, I have never yet found the slightest effort on the part of the manufacturers to evade, in the smallest degree, the responsibility for anything they had done. With these two elements combining I believe a good rail will be evolved, but it should not be done in a hurry; to accomplish it in two or three years will be good work.

DISCUSSION.

President: Mr. Trimble is present and, as he has had much experience in keeping rails in condition for the safe passage of trains, we would appreciate hearing from him.

Mr. Trimble: I came here tonight for instruction. I was very much impressed with one point Mr. Metcalf made, and that is the necessity of giving the steel proper heat treatment. The railroad people agree with Mr. Metcalf on this point, and we would be very willing to accede to his wishes in the matter of heat treatment. We know that it is very necessary that the rail be rolled with certain temperature limits and not too hot, and we also believe that we would get a better rail

when it is rolled and finished at a low temperature. With regard to the types of breaks Mr. Metcalf has described, his information is quite different from ours. One would infer from Mr. Metcalf's remarks that the moon shaped break in the base of the rail is the one that occurs most frequently on the railroads. Out of 200 rails taken out of the tracks recently on the Lines West of Pittsburgh, and assembled at one place, there were not more than five with the moon shaped breaks. In fact, we do not have many broken rails at all; the rails were removed from the track principally because of flow of metal in the head, or split or crushed heads. We find a good many rails that split off on the head and we would be very glad to have the steel men make us a rail without that grain in it which produces these splits. We do not know why this occurs, but of the 200 rails taken out of the track on account of various causes, it is fair to say that 80 per cent. were from material that appeared soft and simply crushed down or spread out until the rail could not be kept in the track any longer.

Mr. Wendt: As Mr. Trimble has stated, the largest number of failures are in the head. I know there is a common impression that there are many failures of the moon shape, but the facts do not bear out that conclusion. Contrary to all newspaper reports the number of broken rails is very low, not exceeding one per mile per year; in other words, there are very few rails taken out of service because of being broken. Replacements are made on account of flow of material, or breakage due to rail being split, piped, etc. The one point I wish to emphasize is that there are very few broken rails in proportion to the large tonnage on the tracks.

What the railway people are looking for is a better rail, and that is an exceedingly difficult problem—one which nobody seems to have worked out as yet. Mr. Metcalf has thrown a great deal of light on the question of steel making, but I would like to have him tell us how we are going to get these improved rails. The change of section, according to his experience, is certainly along the right line, the distribution of metal

probably being 40 per cent. in the head, 40 per cent. in the base and 20 per cent. in the web. We hope this change of section will bring about the desired results, but the deeper one goes into this whole question, the more convinced he is that the problem is not so simple in its solution as it might seem. The principles mentioned by Mr. Metcalf are certainly clear, but what we need to know is how those principles can be applied today to the material in bessemer rails. The importance of the question is recognized by the whole country, but the one impression we should seek to eradicate is that the present rail is unsafe as has been represented by the public press. The facts do not bear out that impression at all.

Mr. Metcalf states that the stress in the rail is generally recognized as 11000 lb. As a matter of fact, under the rolling loads these stresses are very high, much beyond that, and this very fact makes it all the more necessary that the rails should be of the very best. The problem is exceedingly complex, and personally I think the steel makers are doing fairly well under all the conditions that surround their business.

Mr. Metcalf: In regard to breaking, I do not speak at all from my own knowledge. One of the technical papers, in an article written by a man who professed to be a railroad engineer, states that 98 per cent. of the breaks he was familiar with, were of the moon shape, and a very prominent railroad officer in Pittsburgh told me that the great majority of breaks on the Pennsylvania Lines were also of that shape.

Mr. Trimble: I think Mr. Metcalf is excusable for his statement in regard to moon shaped fractures. Several of the railroads in the country seem to have had quite a number of these breaks and they have been advertised thoroughly. At a meeting in New York in the middle of January there were about 14 representatives of a number of large railroads. It was developed that moon shaped fractures were not prolific on the lines represented at the meeting.

Mr. Ferrara: (Non-member.) I believe the trouble lies not alone in the methods of rolling, but also in the heating and

even in the making of the steel. I believe the heat in the converter is too high, and that better steel was made and fewer pipes encountered when the heat was blown from 15 to 18 minutes. We should leave the ingots in the heating furnace a longer time before rolling and the rolls should have more passes with less reduction in each pass.

Mr. Prichard: One phase of the rail question that ought to be considered is the service required of the rail under modern conditions. The general public, and to some extent the railroad engineers, are too prone to attribute the increased difficulties to the quality of the rail. During the past 25 years there has been an increase in the severity of the usage to which the rail is subjected, and but little change has been made in the roadbed. The ballast remains about the same, and the ties, if anything, are now smaller owing to the increasing scarcity of timber.

The weight on the locomotive driving wheels has greatly increased, and owing to increase in train speed, the pressure from the centrifugal action of the unbalanced portion of the driving wheels has increased from 20 to 25 per cent. of the weight on the drivers, all causing an increase in the shock which the rail receives. Further, the present relative inferiority of the roadbed and ties tends to increase the strain in the rails, and the increased frequency of heavy loads develops fracture from overstrain in a much shorter time than formerly. An intelligent solution of the problems which have arisen requires a consideration of the entire track from the top of the rail to the pressure on the earth.

Mr. Baker: I do not think I am violating any confidence when I say that I saw a rail that had been water treated. On the regulation block with the regulation distance between supports, this rail withstood just about ten times as many blows as the average rail of the same steel; but whether the treatment can be applied to rails is a question. The appearance of the fracture of that metal was something wonderful, and when examined not too closely it looked like a piece of splendid iron

that had been torn in two rather than a piece of steel. I believe this Society would do well to take this matter up in a series of practical tests. If a piece of ordinary open-hearth or even bessemer steel be given proper heat and water treatment, it will be many times stronger than a piece of crucible steel, of the same carbon, that has been treated and allowed to cool; i. e., annealed. If the article when forged or rolled is of such shape as to permit heating and cooling treatment, I feel sure that the finishing temperature is not important except that the steel should not be overheated, nor worked so cold as to exert a crushing effect. This is easily proven by tests.

Mr. Lynch: The subject of steel rails is one of very great interest to me, and I am sorry I have not had the time necessary to follow up this question as it merits; but there are those of our number present tonight who are constantly brought in touch with the manufacture and service of rails and who know whereof they speak. The principles involved in cooling strains are such as to indicate quite conclusively that the new section adopted by the Pennsylvania Railroad Company is in the right direction.

Mr. Stucki: Some years ago extensive tests were made in heat treatment and recorded in the proceedings of the British Iron and Steel Institute. It was shown that quenching near the recalescence point produced the best structure, while reheating to a temperature considerably below said point, followed by slow cooling, would avoid brittleness. Steel treated in this manner has been found to be very much stronger, and what is possibly more important, has also been found more ductile and consequently better to resist live loads.

From the manufacturer's standpoint, we must admit that the English double headed rail is the ideal section; but when we flatten the lower head to form a base, we get thinner material with a density different from that at the top, resulting in internal stresses. It is impossible to design a section which will give us an ideal quality of steel and still adapt itself completely to the mechanical conditions, and the best we can do is

to strike a happy medium. The centrifugal force of the counterbalance is very severe on the rail, usually but one-third of the reciprocating parts being counterbalanced. For this reason, on roads where sand ballast is used, these parts are sometimes left unbalanced, which relieves the rail of such shocks, the frames of the locomotive taking them instead. The severe pounding at the rail joints produces heavy strains, far exceeding 11000 lb.

President: Mr. Trimble, do the railroads determine the efficiency of rails by the number of train miles they will endure, or by the number of months they remain in the track?

Mr. Trimble: We have not been able to measure it that way, it is very difficult to get the exact tonnage that passes over a rail. That is the ideal way, but there are very few railroads that can give in in that shape, except on experimental rails. We keep such figures for experimental rails, but not for all.

Mr. Morse: It has hardly been ten years since Carnegie put into operation his railroad to the lakes, which was one of the first to use the heavy steel cars upon the short wheel base of 36 feet. My experience in designing and building bridges has only been about 30 years, yet in that short time the thousands of steel cars and the heavy tonnage put into them has increased the following load three times what it was when I first began designing railroad bridges. Now, instead of using a few thousand pounds for the following load, we have steel cars in operation, especially around our mills, that give a greater wheel base load than the engines of years ago. The use of our steel cars in hauling ores gives us a following load that is like a continuous train of locomotives. That being the case, we can readily understand that the rail is getting a great deal more punishment than it did ten years ago. Yet in the face of that fact, I regret to say that today some of the best railroads are starved in the maintenance of way department. The management has not been giving that department anything like the amount of money they should have to keep up the roadbed. They do not have money to put the necessary drainage into a

roadbed, and they do not have the amount of money to equip the roadbed with ballast that they should have. I was simply horrified last fall to see, on one of our best railroads where we have one of our highest speed trains running, that there was literally no clean ballast under the ties. This was my observation on two other roads of like travel and standing. That being the case, I cannot help but feel that part of the blame should be charged to the railroads; I cannot help but feel that the steel makers have kept up to the conditions of increased traffic fully as well as the railroads; and when I see our heavy trains passing over our best railroads today, with the rails fairly jumping off the ties and pulling the spikes, I cannot help but feel that all the conditions should not be attributed to the rail. I am not criticising our engineers who have charge of our local railroads, but I am criticising the management. I am criticising those who distribute the money with which our well known local engineers have to make good. We all know that the duties required of the rail are many times more than they used to be. We know the rail has been increased in section to meet that condition, but it is a distinct disappointment to find that the railroads have not kept up with the roadbed, and until they do, I question if the problem will be solved, no matter what the steel, bessemer or open-hearth, or what sizes or what sections are adopted.

Mr. Hardie: It is very well known what a factor steel cars have now become in the transportation business throughout the country. The 50-ton steel hopper car was introduced by the Carnegie steel company, in 1896, when two such cars built at their Keystone bridge works were put into actual service conveying ore from Lake ports to the Lucy furnaces.

I can very well recall, when it was decided to exhibit these cars with others at the Saratoga convention of the Master Car Builders in June, 1896, it was distinctly stated by the railroad company which was to haul this exhibit of steel cars that, if the hopper cars were to be loaded, such loading must not exceed 80,000 lb. This, added to the weight of the car itself,

would give as heavy wheel loads as the permanent way and bridges would permit. In 1897 the P. B. & L. E. railroad ordered 600 similar 50-ton steel hopper cars. Since that date, the steel car industry has grown and the demands arising from the increased loads, have received the necessary consideration in added strength in the rails and bridge structures.

Mr. Flanagan: I was pleased to note that one of the speakers endeavored to allay the popular superstition that steel rails are in the habit of breaking off like pipe stems, but it appears to be admitted that once in a while such a thing occurs. I would like to ask whether that happens with a new rail or whether it is only after the rail has been in extended service and received a good deal of punishment. Does it occur only when settlement or other changes in the roadbed have brought a very abnormal strain on the rail? Will any ordinary railroad service break a rail in good condition transversely?

President: During the few years of my railroading, the rail proposition interested me. If a sight is taken through a transit telescope it will show that all joints are low, giving the rails the appearance of being curved in a vertical plane. We were not concerned about rails breaking during the summer months, but as soon as the season changed to cold weather with sharp frosts, we expected to find fractured rails, the break generally occurring across the web. We do not recall any instances where a rail failed during the early period of service.

Is not the hammering effect of the wheels on the low and loose joints, as destructive as a blow from a steam hammer? We did not have an opportunity to study the fractures, but may not this hammering effect explain the crystalline structure? We would appreciate hearing Mr. Metcalf's ideas in regard to this feature.

Mr. Metcalf: Whether iron or steel in long use change their structure by crystallization has been a mooted question for many years, but I very much doubt that large crystals are so formed. On the other hand it is absolutely certain that by cold working you can change the structure of the steel to some

extent, but in my experience it has always been in the other direction, it makes the grain finer. If you overroll a piece of steel, roll it too cold or too hot, you will find the grain very hard and the center of the piece black. If you overdraw wire beyond the limit of elasticity you will find a black core in the center of it. I have never found any large bright crystals as the result of such overworking, and I have an idea that where they occur in the fracture they were there originally, and that the fracture was caused by the continued strain that went just beyond the elastic limit. We had an entire heat of nice open-hearth 12 in., 6000 lb. billets, some of which had been sent out all over the country. In breaking open one of these billets, we found at least six inches of its center perfectly black, which was caused by what is termed a wild heat. One gentleman says they are blowing the heat too hot. It may be that they are, but it is far worse to have them underblown.

REGULAR MEETING,

March 17th, 1908.

President J. K. Lyons

In the Chair.

ELECTRIC POWER IN IRON AND STEEL MILLS.

By W. Edgar Reed,*

Member.

In all modern industries where power is transmitted some distance or distributed over considerable areas, the electric motor is continually acquiring greater prominence; and work which was originally performed by man and later by beast, has been gradually transferred to other and more powerful agents as means have been found to control their operation. Every advantage gained in controlling these forces has led to a marked growth in the industry where they have been applied. An example of this rapid growth is the application of electricity to the operation of street cars, and similar revolutions are now taking place in many industries due to the application of electric power. The control of power generally becomes more difficult as the driving units increase in size and when they are applied to individual machines with varying requirements in regard to speed, torque, power, etc. Some machinery, for example, may require variable torque at a variable speed; some, constant torque at a constant speed; others, variable speed at a constant torque, etc.; special conditions and requirements arise in nearly every new application of motors to individual machine drive.

The increasing application of electric drive in iron and steel works is due partly to the economy in transmission and distribution, partly to its reliability and partly to the ease and facility of control. Electricity offers also, in many cases, the most efficient and elastic system of power transmission. It requires simply a few properly insulated wires for the transmis-

Consulting Electrical Engineer.

sion of great quantities of power for long distances and with a small percentage of loss. A part or all of the load can be easily and quickly changed, cut off or thrown on without injury to the system. These features permit the centralization of the smaller generating stations required by other systems, the averaging of the intermittent and varying loads and effect a generally increased production. This means a great reduction in the cost of power and in the capacity of the stations. Generally a central power house need only have from 25 to 33 per cent. of the combined capacity of the auxiliary motors.

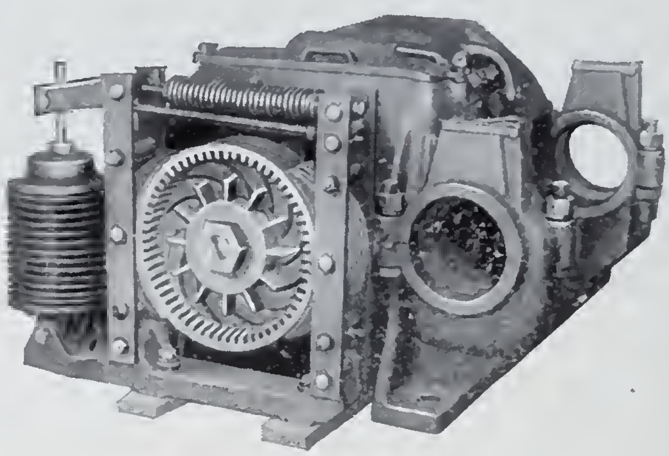


FIG. 1. Motor and Electrically Operated Brake.

Heavy mill work requires a drive capable of withstanding intermittent excessive loads and, in order to reduce the cost of repairs to a minimum, requires a very flexible coupling between the prime mover and the rolls. Electricity offers the most flexible connection known and is the system best suited where excessive variations in power are required. These advantages are so well understood and the system has been so thoroughly tried that there is no hesitation in using electric drive for all the auxiliary apparatus and for even the most severe and exacting conditions met in large continuous or reversing roll work. The waste gases from blast furnaces offer a comparatively cheap source of power when used in connection with an electrical installation, and are utilized for this purpose where the cost of fuel is comparatively high; and even in the United States where coal is very cheap, the use of blast furnace gases for power purposes has been found advantageous. When

power for a mill is bought from an outside company which also furnishes power for purposes requiring good voltage regulation, large fluctuating loads might be objectionable; the excessive intermittent loads common in mill work may be large compared with the capacity of the power station and seriously affect the voltage regulation, especially if motors be used for driving the main rolls. The maximum power required, although it may last for a short time only, determines the maximum size of the station and the cost of power; for this reason power is often sold on the basis of the maximum instead of the average or total power consumed. It is, therefore, desirable to reduce the maximum demands or peak loads as much as possible in order to secure improved regulation and to reduce the cost.

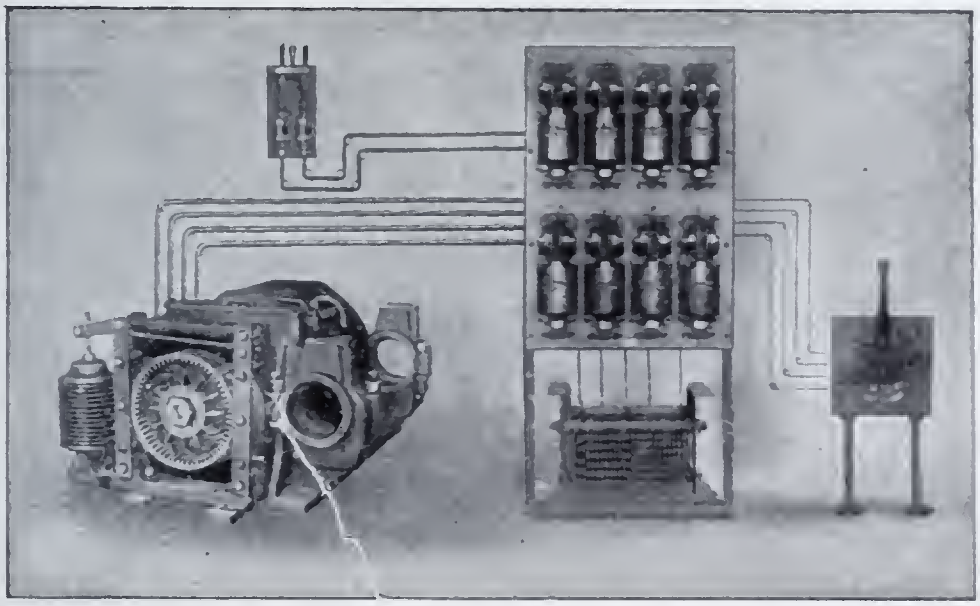


FIG. 2. Mill Motor, with Brake Operated by Motor Controller, and Magnetically Operated Switches.

DRIVE OF AUXILIARY APPARATUS.

The first application of electric motors in steel mills was made about 1892, when they replaced steam-driven and other types of hoisting apparatus, and were also used for operating overhead cranes. The crane applications were of the greatest importance; no installation is considered modern without the electric crane, and no one who has had experience with it would think of replacing it by any other type.

The application of electric motors was next made to the operation of charging machines for open-hearth furnaces and to machinery for the handling of blooms and slabs. Electric motors have also been used extensively for the operation of roller tables where ease of operation and time required in handling material is of the greatest importance. The application of the motor has also been extended to screwing down rolls of bloom, slab, plate and other mills; lifting and rotating blast furnace bells; tipping bessemer converters; operating transfer tables, saws, shears, bending and straightening rolls, blast furnace hoists, ore and coal conveyers and all the auxiliary apparatus in iron and steel mills. In a few instances motors have been used for operating blowers for bessemer converters but in most cases blast furnace gases are used directly in gas engine driven blowers. For the purposes mentioned, either the direct or alternating-current variable-speed types of motors are universally used. (For operating characteristics of motors refer to Proceedings of this Society, October, 1905.) This type of motor is suitable for developing variable speed at variable torque, and is applicable where frequent starting and reversing with large torque are required. Less energy is required to perform these operations with this type of motor than with other types.

For the operation of continuous rolls, saws, cross and straightening rolls, punches, shears, etc., where fairly heavy starting torque and continuous operation in one direction are required, and at the same time where the load may be greatly diminished or taken off the motor entirely, the compound type alternating or direct-current motor is generally used. In work with varying torque, this type gives less variation in speed than the variable-speed motor, and the maximum speed is limited to a suitable safe value at small loads. The first motors put in general use for the classes of work mentioned, were of the street railway type, suitably modified mechanically for mounting on foundations, cranes and machines, and in some cases, with changes in the windings. Later designs, however, have been

changed greatly and have been made heavier and stronger to better meet the conditions of mill work.

Motors for intermittent mill work require a design quite different from that used in any other class of service. They are not only subjected to heavy intermittent duty, large starting and accelerating torques, and shocks due to sudden variations of load, but they must also withstand rapid and continued reversals. Some of the features of up-to-date direct-current mill motors are as follows: Strong cast steel horizontally-split frames provided with heavy wide-spread feet; the upper frame should be hinged to the lower one and the connections so designed that the motor can be easily opened and armature removed without changing electrical connections; axle-bearing housings, when required, should be cast with and form part of the lower frame; large mechanical clearance between armature and fields should be provided; the armature bearings should be split, interchangeable, dust proof and provided with eyebolts for handling the armature; provision should be made for either grease or oil lubrication; shafts should be extra large compared with those used in railway service and the armature should be built upon a spider so that shafts can easily be replaced; the insulation should be as nearly fireproof as possible, and capable of withstanding the high temperature to which it may be subjected, due to its own heating and the high temperature of surroundings; the motor should be enclosed and provided with tapered shaft extensions on both ends for brake and pinion fits.

Mill motors are generally rated on the ½ hr. full load 40° C. temperature-rise basis. For given applications they should be chosen by determining the average losses for a cycle of operations, and comparing these with the losses different motors will stand with a satisfactory increase in temperature. The maximum temperature is one element in limiting motor capacity, and the temperature of the place where the motor is installed must be carefully considered; in making these comparisons the maximum torque, etc., required at any time must be considered. A voltage of 220 has been used more often than

any other and may almost be considered a standard; the danger of a shock from grounding a 500-volt circuit has generally been a strong argument against this higher voltage. These general features can be applied to alternating-current motors. The split frame is very seldom used with these motors, however, and the brackets are made in such a way that they can easily be removed and the armature slid out of the frame along the direction of the shaft. In such a motor it is advisable to have split brackets, and the bearings should be separate from the brackets to give access to any part of the machine. The use of the electric drive to all the auxiliary apparatus in iron and steel mills, partly described above, has been gradually increas-

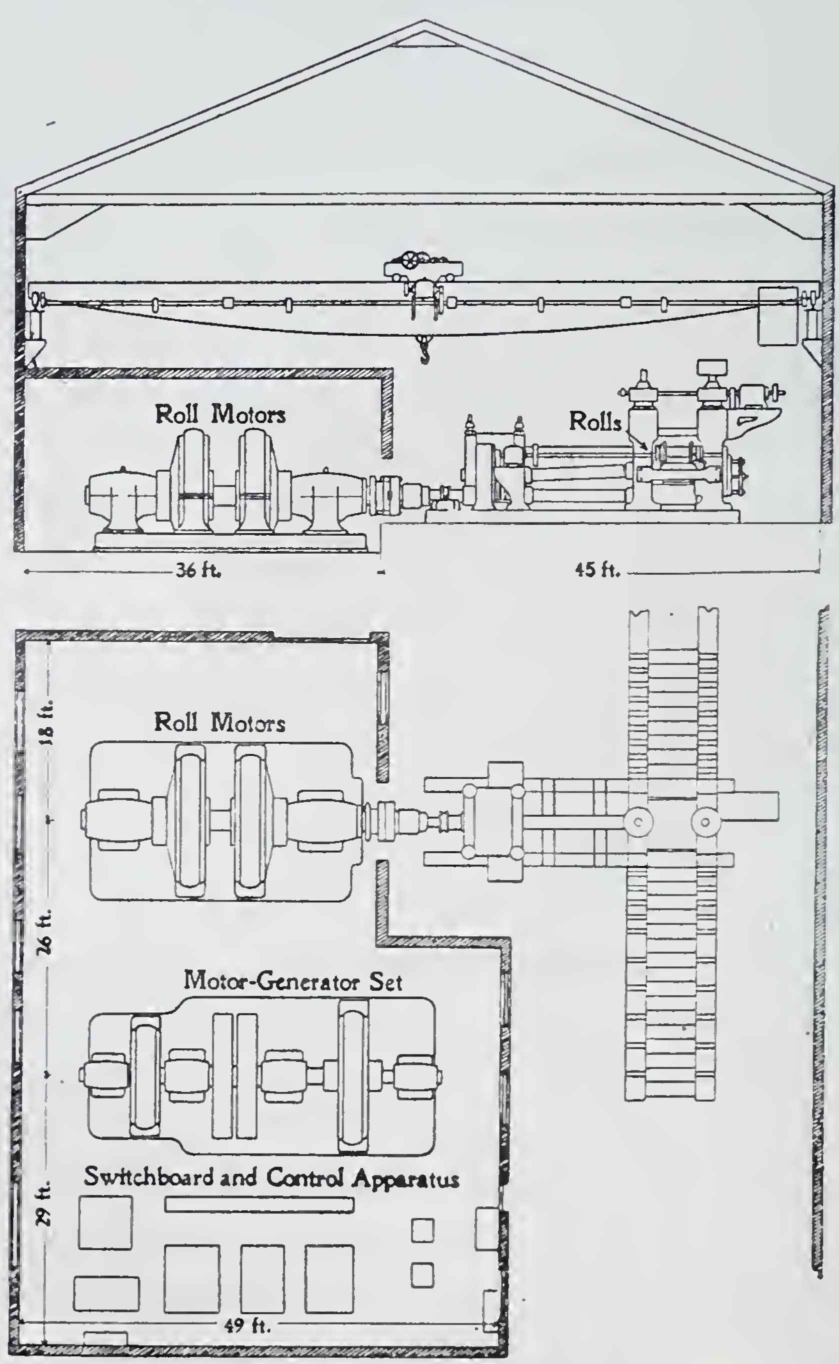


FIG. 3. Arrangement of Electrical Units and Control.

ing since 1892. The drive of the main rolls has been a more difficult problem on account of the size of units and character of the load, and such installations are only of comparatively recent date; they are, however, of great importance and interest and are attracting the attention of both engineers and manufacturers.

DRIVE OF MAIN ROLLS.

The excessive intermittent loads when the roll motor is large, as compared with the capacity of the generating station, may cause great fluctuations of the power house load unless an equalizer is used. For the auxiliary apparatus each motor is very small compared with the capacity of the generating station, and large variations in its load would have but little effect at the power house. This is particularly true when many of these motors are using energy from the same power house, because part of them would be operating at heavy loads when others are carrying light loads, the average load being fairly uniform. With main roll motors, however, this is not the case, and variations are so large that they may in some cases be troublesome to handle in an economic way without some kind of an equalizer. Some idea of the variations in torque and power required for operating main rolls may be obtained from figs. 4 and 5. Fig. 4 shows the variations of speed, torque and horse-power for different passes and at different times during the operation of a reversible 30 in. plate mill. In choosing a motor for any particular installation, curves similar to these may be determined from indicator diagrams of existing similar steam engine driven installations. The rolling speed is determined from the number of passes required for given reductions in section, intervals between passes and the time required for acceleration with a given available power, speed of rolls when material enters and leaves them. The torques required at roll surface for different passes or reductions of sections at certain temperatures, to overcome friction and to accelerate masses, are then determined; curves showing power required for elongating material are convenient in this work; having the speed

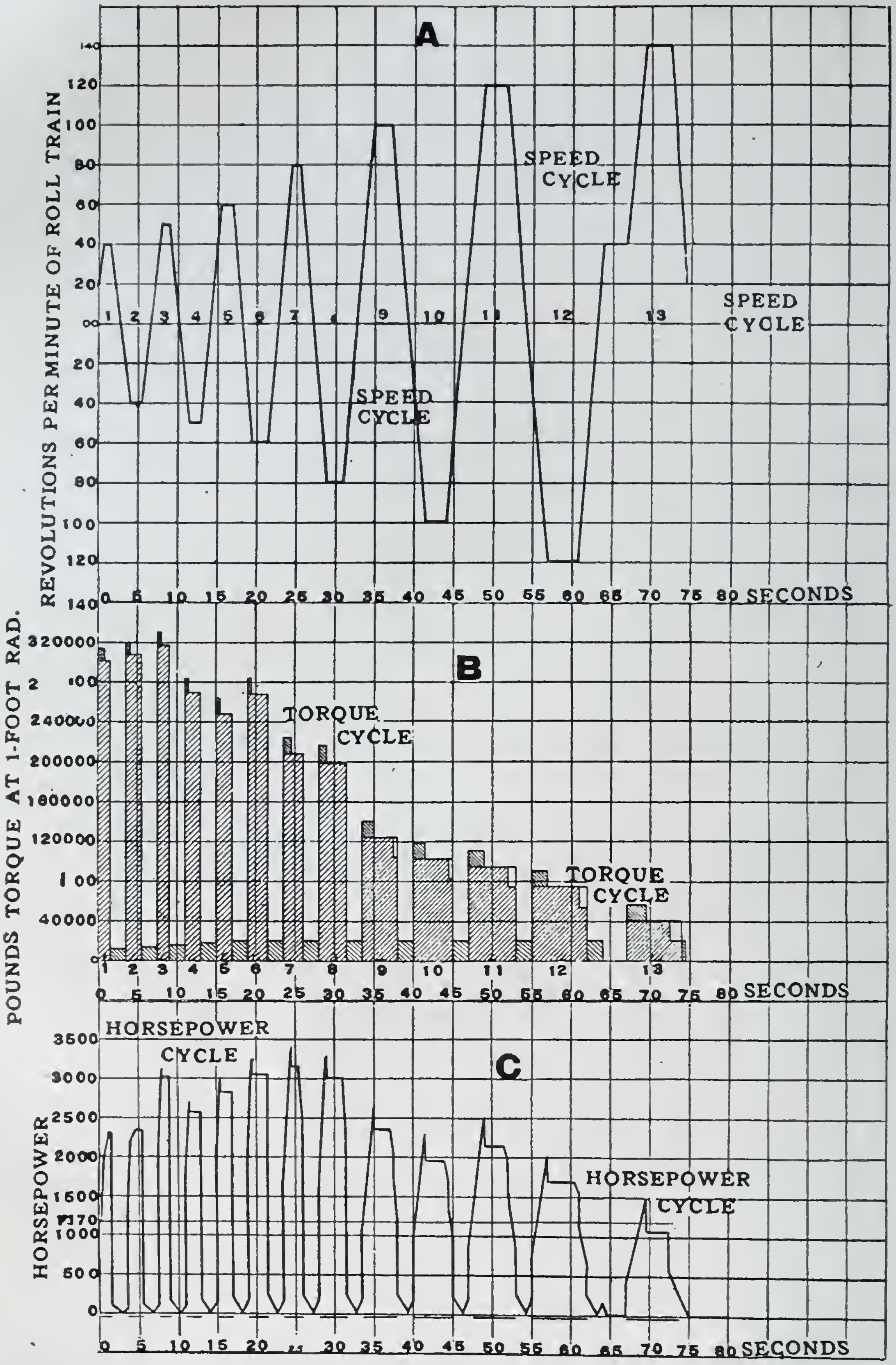


FIG. 4—SPEED, TORQUE AND HORSEPOWER CURVES, SHOWING REQUIREMENTS OF 30-INCH REVERSIBLE MILL.

and torque curves the power curve can readily be constructed. The reduction of section and required torque become less with succeeding passes, and the speed of rolling can be increased so as to keep the time required for passes as low as practicable and at the same time keep the maximum peak within suitable

limits. This integrated power curve shows an average horse-power of about 1200, which is approximately one-third of the maximum. Fig. 5 shows the variations of torque, horse-power, and speed in the operation of a 1500 h. p., 3-high, continuous rail mill. The speed drops and kinetic energy is given out when material is being rolled, and, increasing to the normal between passes, stores up energy to repeat the cycle.

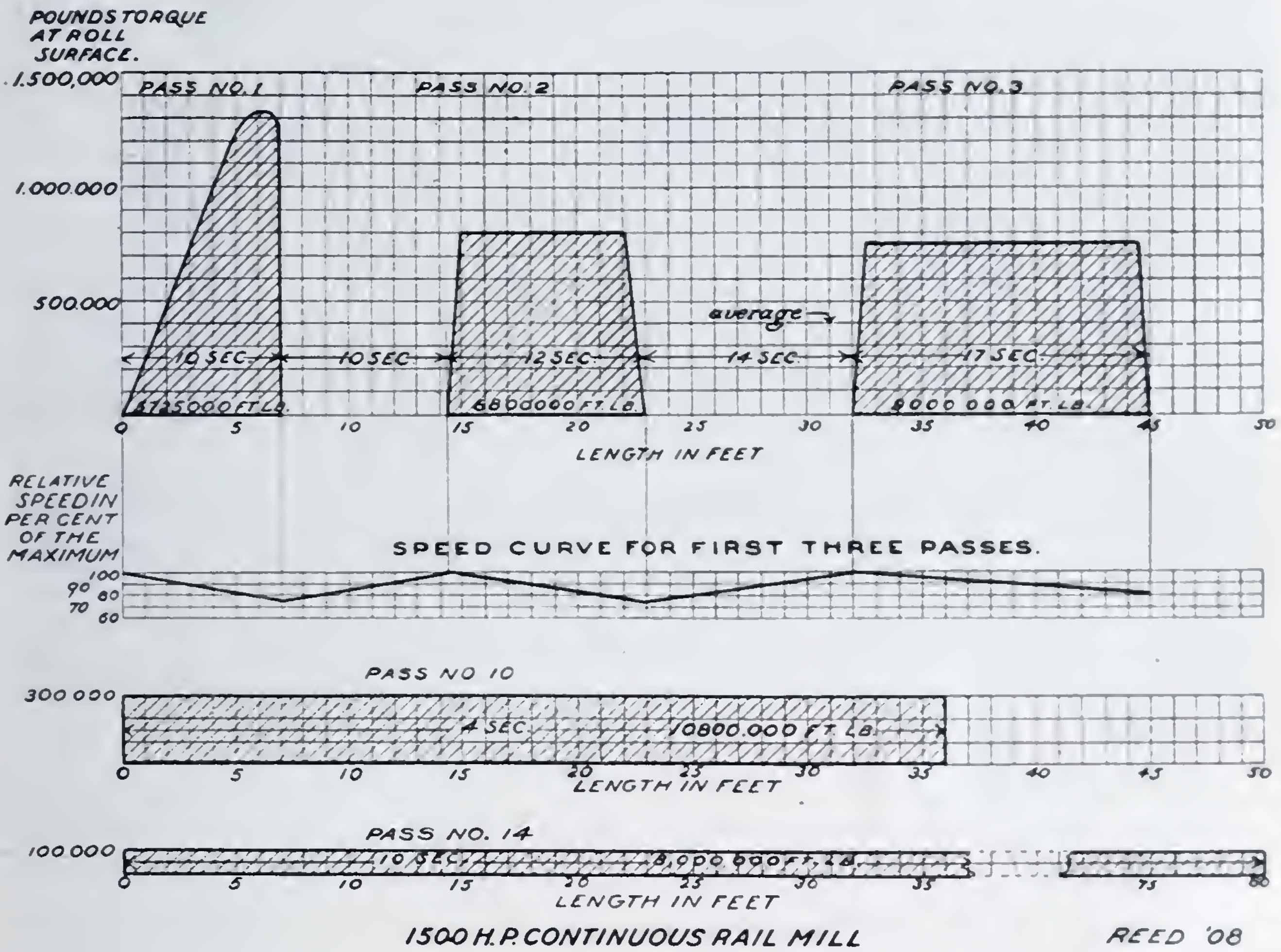


FIG. 5. Variations of Torque, Horse-Power and Speed in Operation of 3-high Continuous Rail Mill.

Steam engine driven reversible rolls operating at widely varying loads would have low average efficiency; the simple non-condensing engines generally used, when operating at fairly constant loads, are not as efficient as other types. The repeated shocks on machinery, gears and bearings have a tendency to cause considerable wear, breakage and repair.

In the electrical operation of such mills, some method must be used for equalizing these excessive variations and peaks before they reach the power house, to make the load

more nearly constant, bring it closer to the rated horse-power of the plant, and effect a higher average of efficiency, lower maximum capacity of power house apparatus, and lower cost for power. Opposing these advantages, however, there must

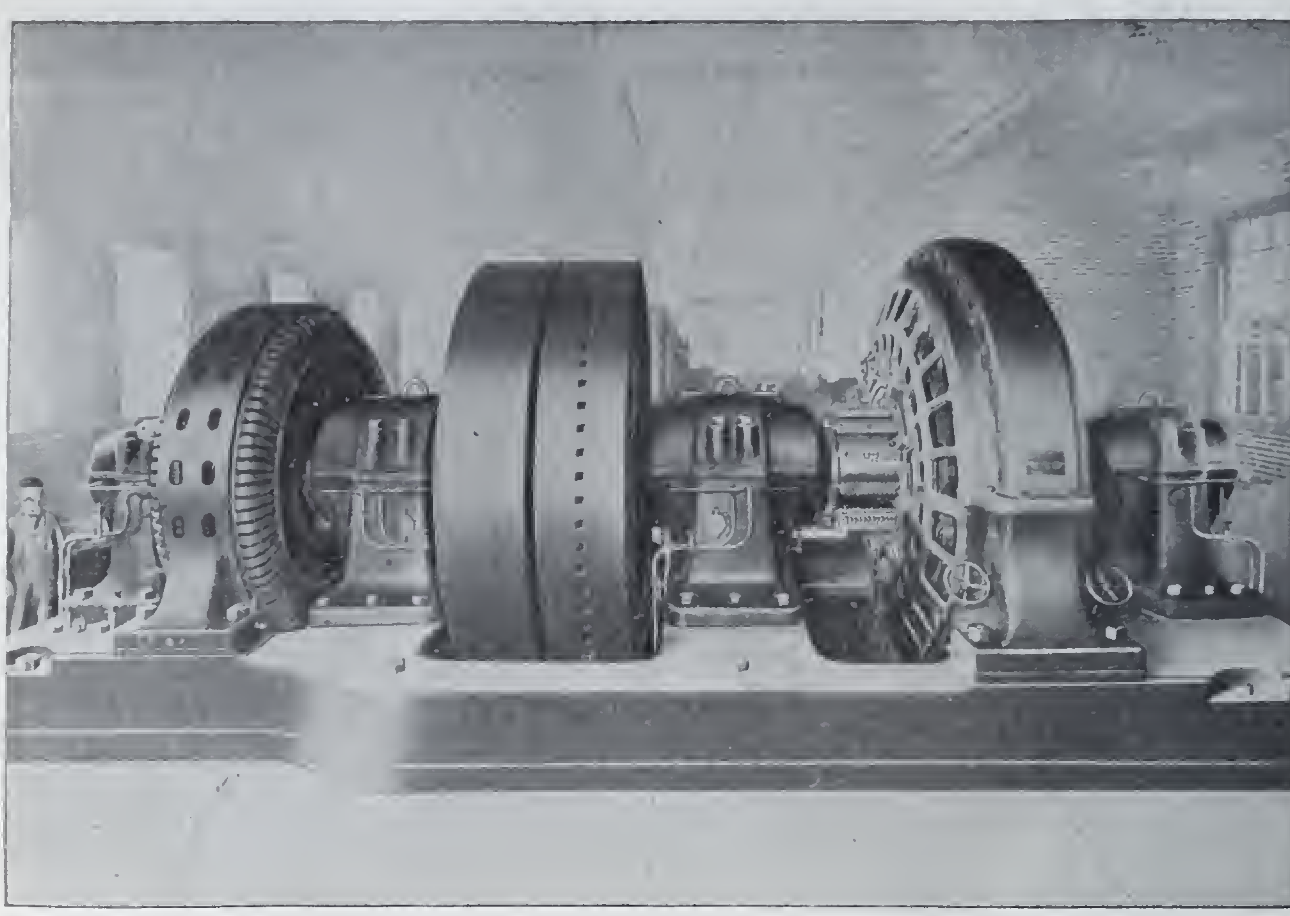


Fig. 6. Equalizer Set for 30 in. Universal Mill.

be considered the extra cost of the equalizer set and controlling apparatus. If there are two or more main roll motors whose cycle of operations are not identical, or which cannot be operated at the same time, equalizer sets will be required for each motor.

METHODS OF EQUALIZING.

In continuous mills where the peak load is of short duration, the peaks and light loads can be changed to a fairly uniform value by increasing the kinetic energy of the rotating parts, which may be accomplished by increasing the weight of the rotating element or by placing a fly-wheel on the motor shaft. The speed of the mill motor must drop with the increasing load in order to utilize the stored energy in the ro-

tating element. The greater the fly-wheel effect, the greater will be the equalizing, with a consequent reduction in the overloads on the motor. By using a suitable fly-wheel design the overload on the motor can be any practical value desired.

METHODS OF EQUALIZING REVERSING MILLS.

The kinetic energy of reversing parts should be a minimum in order to obtain quick reversals and keep the energy loss to a low value. Fig. 4 shows an example of the frequency of such reversals, which requires an equalizer differing from that used with continuous mills.

One form of equalizer suitable for these requirements consists of a motor-generator fly-wheel set connected between the roll-driving motor and the source of power. The general arrangement and connections for such a set are shown in fig. 9. This system has been found very efficient in equalizing the large variable and intermittent loads found in large reversing mills, and may also be used to good advantage in many small mills.

This equalizer set, shown in fig. 8, consists of an induction motor with an external resistance in the secondary circuit, driving a fly-wheel and a direct-current generator. A direct-current motor having drooping speed characteristics could be used in place of the induction motor. The direct-current generator is electrically connected to the roll motor, the operation of which is controlled by the simple and easy method of regulating or reversing the generator field current, which is small and of low voltage. In slowing down, the field of the generator is weakened and the roll motor reverses the current through the generator, thus tending to motorize the generator and act as a dynamic brake on the roll motor. Both motor and generator may have auxiliary poles to insure good commutation.

The alternating-current motor is of the wound-rotor type which permits the use of variable resistances in the rotor circuits and the use of a slip regulator for producing variable speed. By the use of this equalizing method a nearly constant

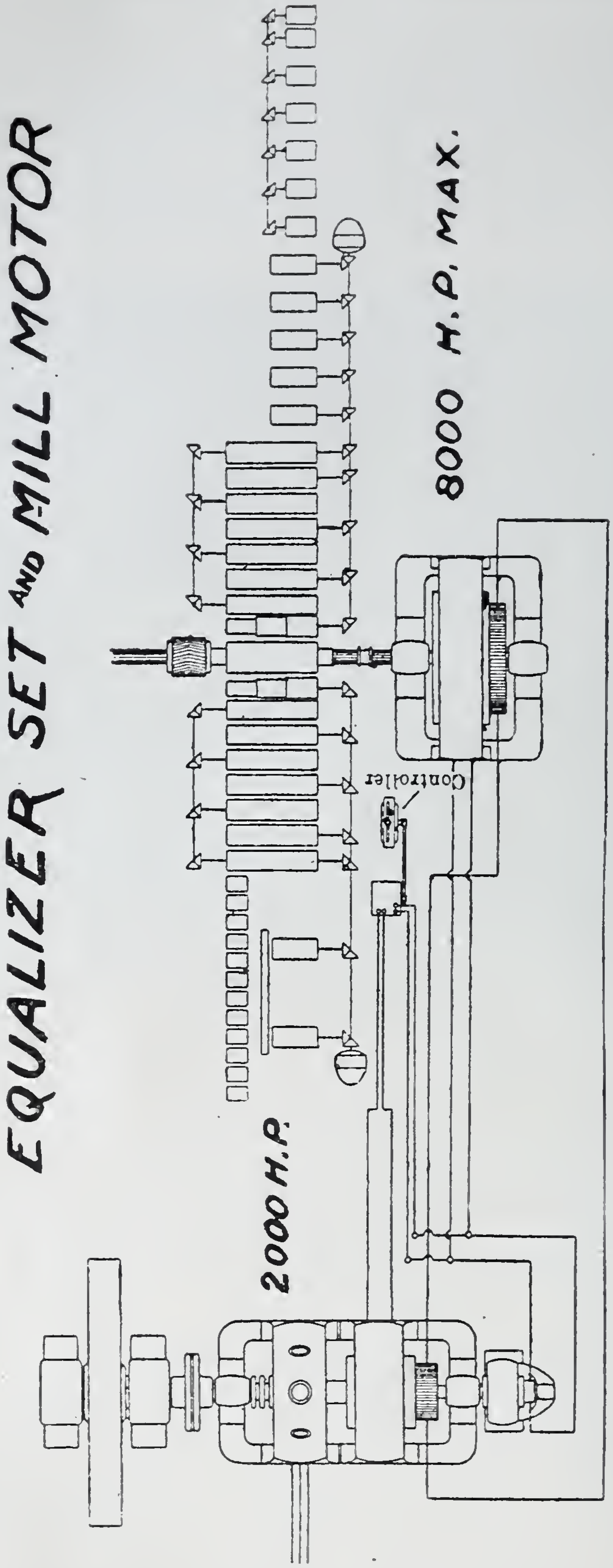


FIG. 7.

supply of current may be taken from the line independent of the power being delivered by the roll motor. When the load comes on the direct-current generator, the fly-wheel gives up energy and supplies that portion of the power required in ex-

cess of the average. Under excessive overloads, the greater the reduction in speed, the greater will be the amount of energy given up by the fly-wheel, as the kinetic energy in the wheel is proportional to the square of its speed. This is accomplished by making the speed of the motor automatically adjustable by inserting resistance in the rotor winding and thus varying the slip.

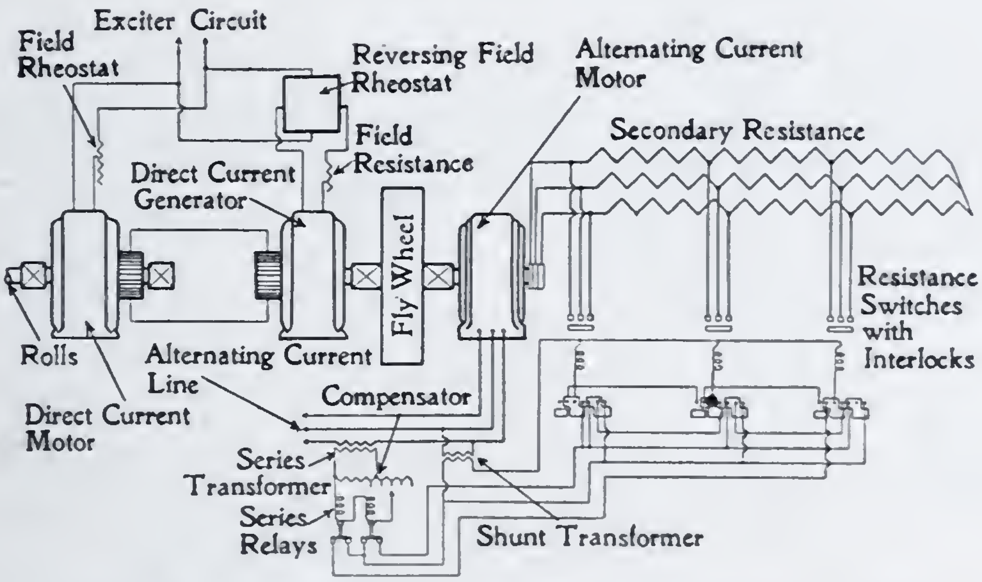


FIG. 8. Diagram of Connections for Equalizer Set.

Two relays are placed in the circuit which supplies the induction motor. These relays are arranged to change the secondary resistance of the rotor so that the motor may drop in speed as the load increases and prevent drawing a greater current from the line. Both relays are closed when starting or at light loads. As the speed increases, the resistance switches are closed by the rotor current, first one, then two, three, four, etc., until the current in the induction motor reaches the desired maximum, when the first relay opens the auxiliary circuit so that no more switches can close. When a heavy load comes on, the fly-wheel gives out energy and slows down allowing more current to be taken from the line. This causes the second relay to operate and cause the resistance switches to insert more resistance in proper order again. This adjustment forces the fly-wheel instead of the motor to take the greater part of the intermittent load by giving up part of the kinetic energy stored up before the overload came

on. This equalizes the irregularities, gives a fairly constant load on the induction motor and all other apparatus back of it, and procures good line voltage regulation.

The slip required of these motors depends upon the value of the peak overload, its duration, and interval between peaks, as well as upon the fly-wheel effect of the rotating parts. It can generally be adjusted for values up to approximately 20 per cent; a motor having 16 per cent. slip at full load would have approximately 24 per cent. slip at 50 per cent. overload. This 24 per cent. decrease in speed would require the fly-wheel and all other rotating parts of the set to give up approximately 42 per cent. of their total kinetic energy; the speed decreases during the passes and increases between them.

CONTINUOUS MILL.

Among the many installations recently made is the following: Two 1,500 h. p., compound-wound, 220 volt, 100 to 125 r. p. m., direct-current motors at the Edgar Thomson steel works for driving continuous rail mills. These motors are direct-connected to the rolls, and special attention has been given to mechanical design. The bearings are of the oil ring and forced circulation babbit-lined type, 25 in. in diameter by 62 in. long, and are arranged for water-cooling. The motor is also very liberally designed and commutation is exceedingly good. A 125 000 lb. cast steel segmental fly-wheel 18 ft. in diameter is mounted on the motor shaft to assist in equalizing the load on the motor and power house. The speed of the motor drops from approximately 125 to 90 r. p. m. in actual operation, which allows the fly-wheel to take care of the peak loads.

REVERSING MILLS.

Installation at the Hildegarde Works—(Austrian Silesia). This mill, shown in fig. 9, is for rolling 2-ton ingots down to billets for making beams, rails, etc., and for the first passes should reverse every six to eight seconds. The mill is driven by a 4-bearing set of three direct-current motors. These mo-

tors are connected together by two rigid couplings and are divided into three units in order to keep the inertia of the rotating parts as low as possible, as well as for manufacturing advantages. The normal rating of each motor is 1,200 h. p. at 330 volts, and the speeds obtained are from 0 to 120 r. p. m. The maximum horse-power of each motor is 3,000 which makes 9,000 h. p. total for operating the ingot mill. The mo-

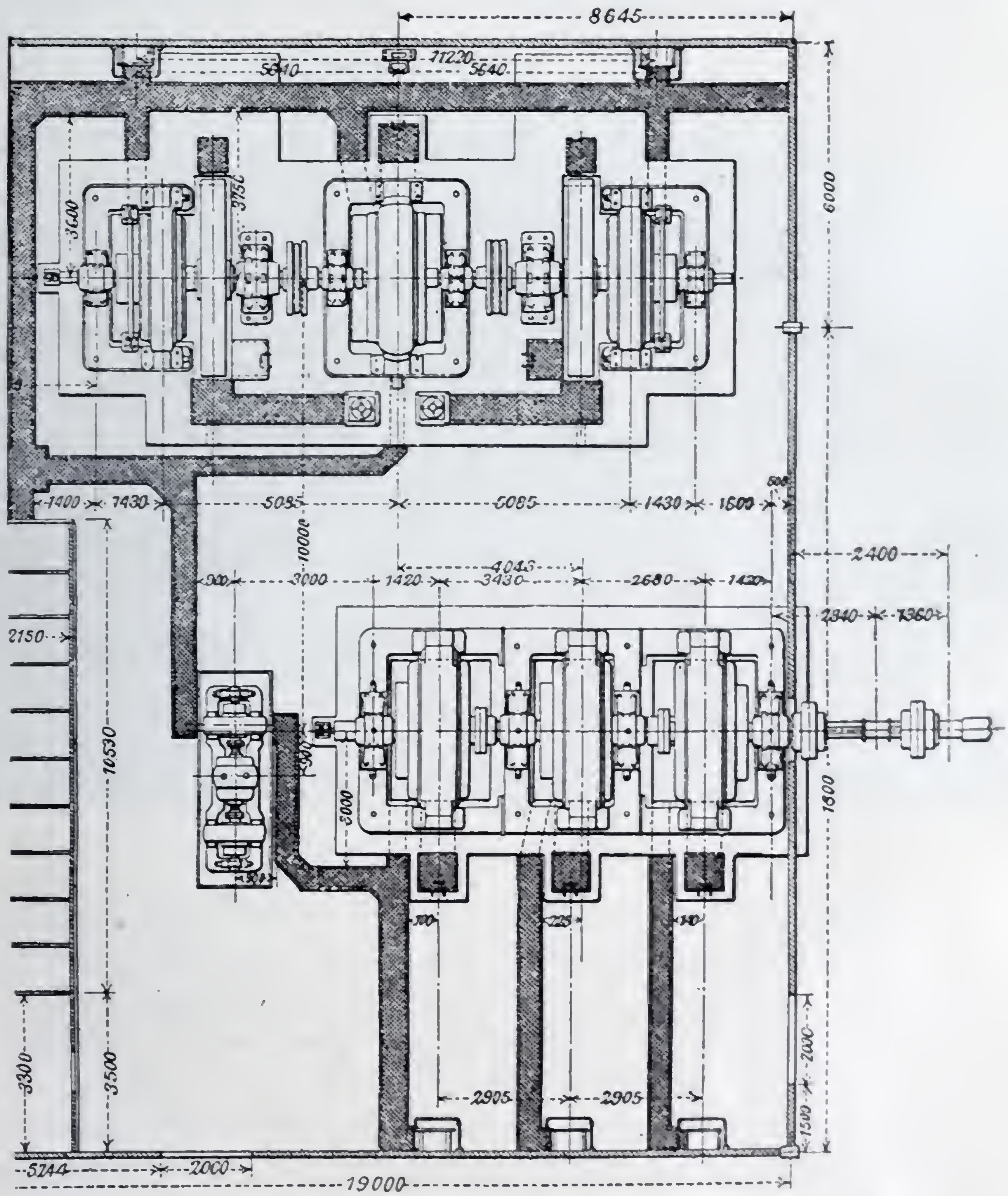


FIG. 9. General Arrangement of Equalizer Set for Reversing Mills.

tors have series and shunt, separately excited windings, and the armatures are connected in series.

The equalizer is a 4-bearing set consisting of an induction motor, two direct-current generators and two fly-wheels, and runs at a speed of from 375 to 310 r. p. m. The fly-wheels are made of cast steel, are 13 ft. in diameter and each one weighs about 26 tons; water-cooled brakes are mounted on the wheels for stopping the set quickly in case of necessity.

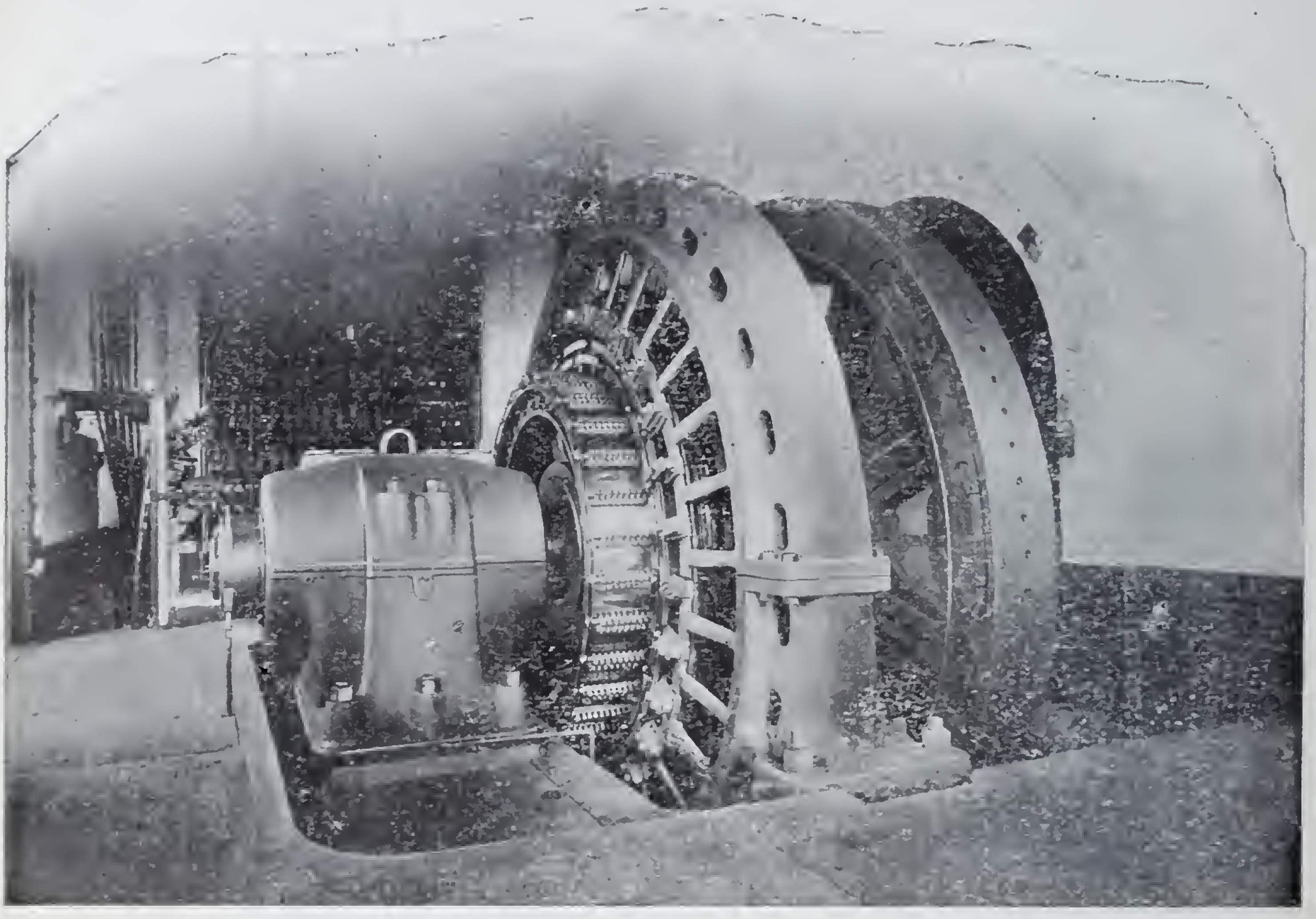


FIG. 10. Direct Current Mill Motor.

The two direct-current generators and the three mill motors are connected permanently in series, the mill motors being controlled and reversed by the field current of the generators. This control is easily and quickly operated. When reversing, the set acts as a brake for the mill motors and energy is returned to the equalizer set. The speed of the induction motor is controlled automatically by inserting the resistance of a water rheostat in the rotor circuit. The generating station

contains one 3,000 k. w., 1,500 r. p. m., and two 1,250 k. w.. 3,000 r. p. m. turbo-alternators. Steam turbines were used in this installation because gas engines would have required considerably longer time to build and install. The power taken from the generating station does not exceed 25 per cent. of the maximum power required for operating the mill.

Fig. 10. This figure shows a direct-current mill motor with thrust collar on housing next to the mill, to take thrust

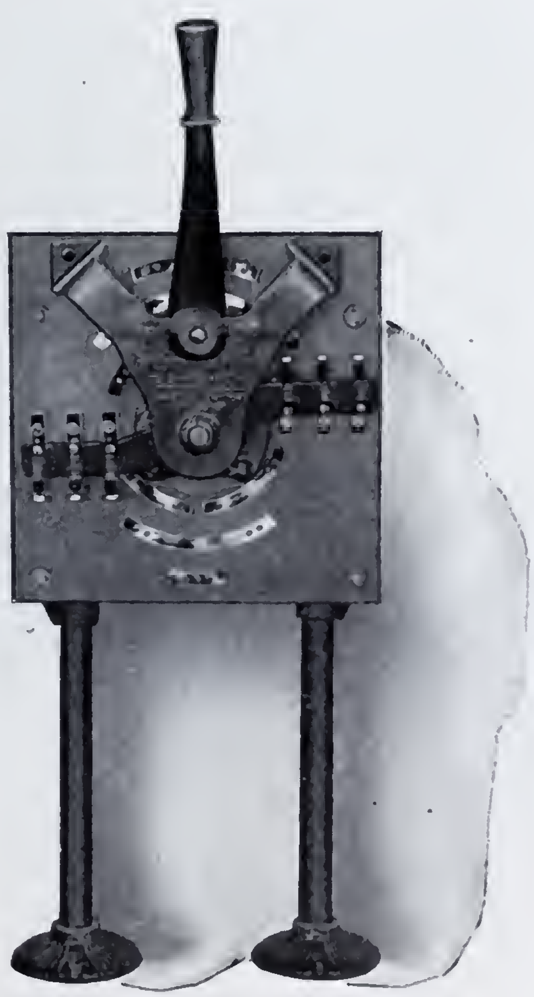


FIG. 11. Master Switch.

in case mill shaft is broken. The motor is provided with water-jacketted bearings, and oil ring and gravity systems of lubrication. The starter for each motor consists of ten large switches mechanically interlocked so that they must be thrown in proper order. All these switches can be tripped from one place, and are arranged to trip automatically when the voltage is off the supply circuit, or when the speed reaches a maximum limit. Old rails are used as resistance and the speed of the

motors can be changed about 25 per cent. by shunt field control.

MULTI-SPEED MOTORS.

Multi-speed motors are used in installations where two or more different constant speeds are required. When direct-current is used, different speeds are obtained by using different field currents. With alternating-current, different speed induction motors mounted upon the same shaft are generally

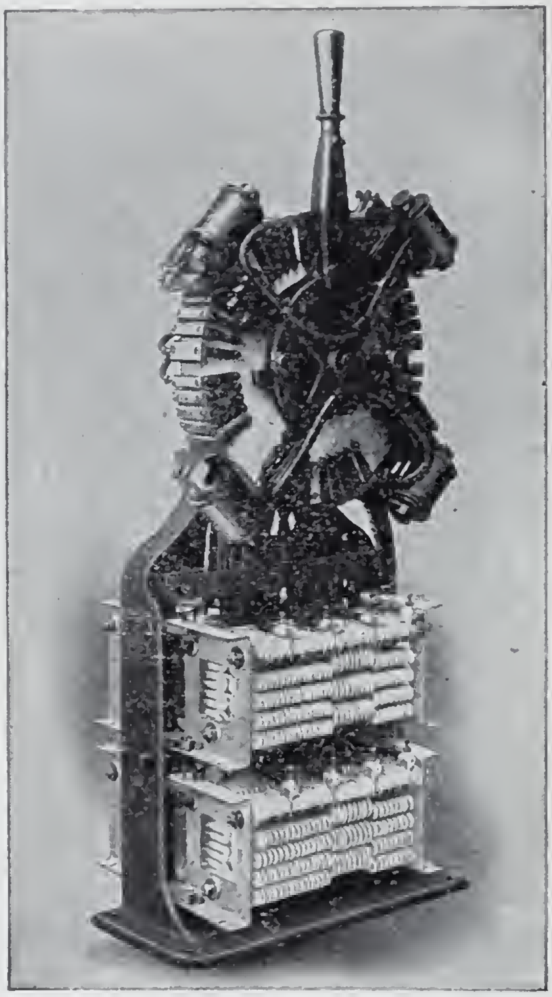


FIG. 12. Rhostatic Controller (with case removed).

used, although recourse may be had to cascade connections; another plan is to provide the motor with one or more windings which can be grouped to give different speeds and may be employed when constant torque is not required over a wide range of speed.

INSTALLATION AT THE ILLINOIS STEEL WORKS.

This 30-inch plate mill is driven by two 2,000 h. p., 575 volt (normal rating), direct-current, shunt-wound motors

mounted on a common shaft. The speed varies from 0 to 150 r. p. m. The mill should be capable of reversing every four to six seconds. Good commutation is secured at low voltages and heavy currents by the use of commutating poles and compensating coils wound in slots in the pole faces. The power taken from the generating station is approximately 30 per cent. of the maximum power used by the mill motor.

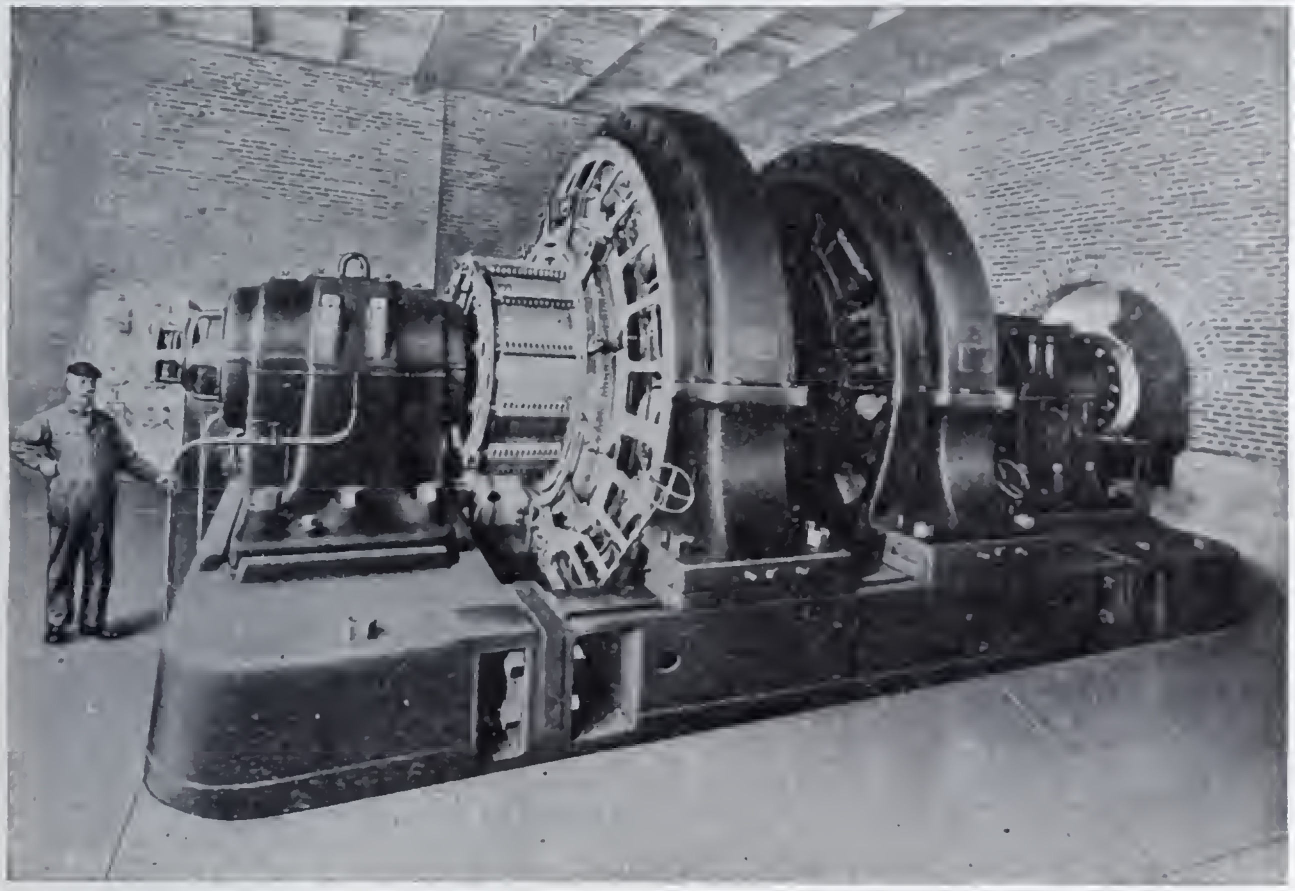


FIG 13. Reversible Mill Motor Set Driving 30 in. Plate Mill.

The torque required for starting and the energy required for accelerating these sets will be high and must be considered in making up designs. If the steel company buys power, such a system would surely be required by the selling company in order to protect its lines from the effects of these greatly fluctuating loads. The importance of equalizing the loads can be seen from figs. 4 and 5. The main roll motor, fig. 4, should have a capacity of 4,000 h. p., while the motor of the equalizer and other apparatus back of it—transmission line, switchboard, generator, engines, boilers, etc.—need only be

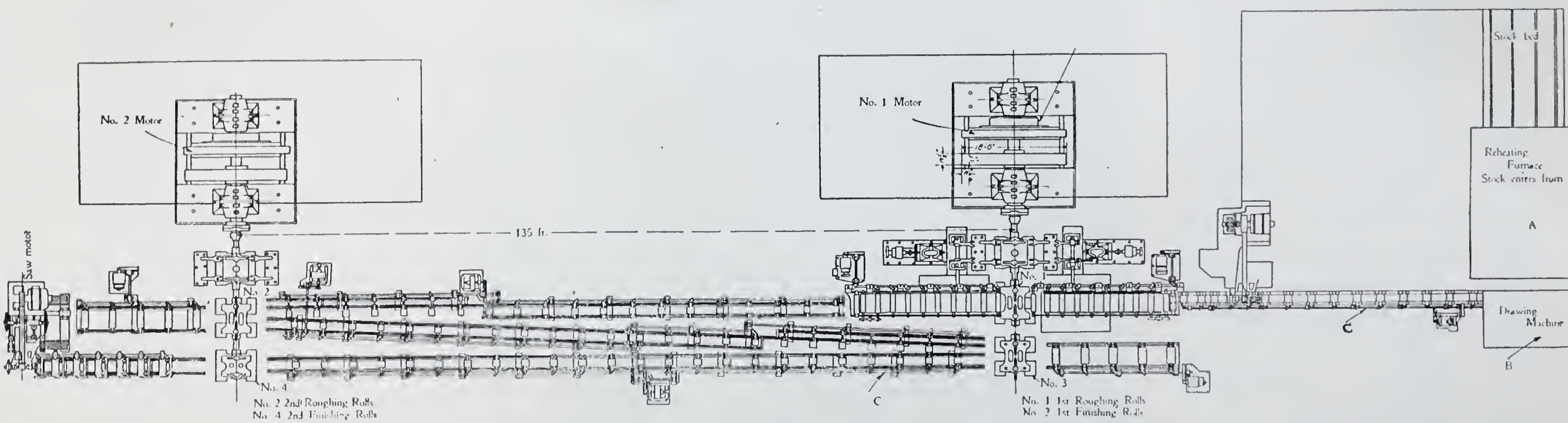


FIG. 14. Plan of Electrically-Driven Rail Mill at Edgar Thomson Plant.

large enough to supply a 1,400 h. p. motor; the average power in fig. 5 is about one-third the maximum.

EDGAR THOMSON STEEL WORKS.

Fig. 14. This figure shows the plan of an electrically-driven continuous rail mill at the Edgar Thomson plant, for re-rolling 50 to 90 lb. rails or billets down to 20 lb. rails or smaller. The mill consists of two trains of rolls, each driven by a 1,500 h. p., direct-current, 220 volt, 125 r. p. m., compound-wound motor. The auxiliary equipment requires about fifteen electric motors for operating such machines as hot saws, straightening presses, drills and cooling tables.

The Gary plant of the U. S. Steel Co., is a remarkable example of electric drive. All the electric power is obtained from generators driven by blast-furnace gas engines, there being only a few steam engines for driving pumps and starting the furnaces. The principal reason for the use of gas engines is that they will produce about 2½ times as much power as could be obtained from the same quantity of gas if used for firing steam boilers and operating steam engines. There is ample supply of this gas for all power and lighting purposes. The gas engines require about 125 cu. ft. of gas per b. h. p. hr. The amount of gas produced, for each ton of pig iron made, besides heating the air blast for furnaces and furnishing power for blowing engines, will furnish 25 b. h. p. for general power purposes. A daily production of 1,800 tons of pig iron would therefore leave about 45 000 h. p. for the operation of other machinery. This company has now ordered electric motors for all auxiliary apparatus, 1,500 h. p. and 6,000 h. p. induction motors for some of the main rolls, and is considering still larger motors for other machinery.

ONTARIO IRON AND STEEL CO.

Fig 15 shows a 22 in. rope-driven blooming mill operated by an 800 h. p., 2,200 volt, 3-phase, 25 cycle, 165 r. p. m. 18-pole, synchronous motor. The power is transmitted from the

motor to the mill by twenty 2-in. ropes, the driving wheel being 10 ft. in diameter and the driven wheel 20 ft. in diameter and weighing 30 tons. The mill handles, as raw material, 8 in. x 10 in. blooms, and turns out as a product 6¼ in. to 7¾ in. skelp and 5 in., 6 in., and 7 in. flats. The bloom is reduced to 2¼ in. square in the first set of rolls.

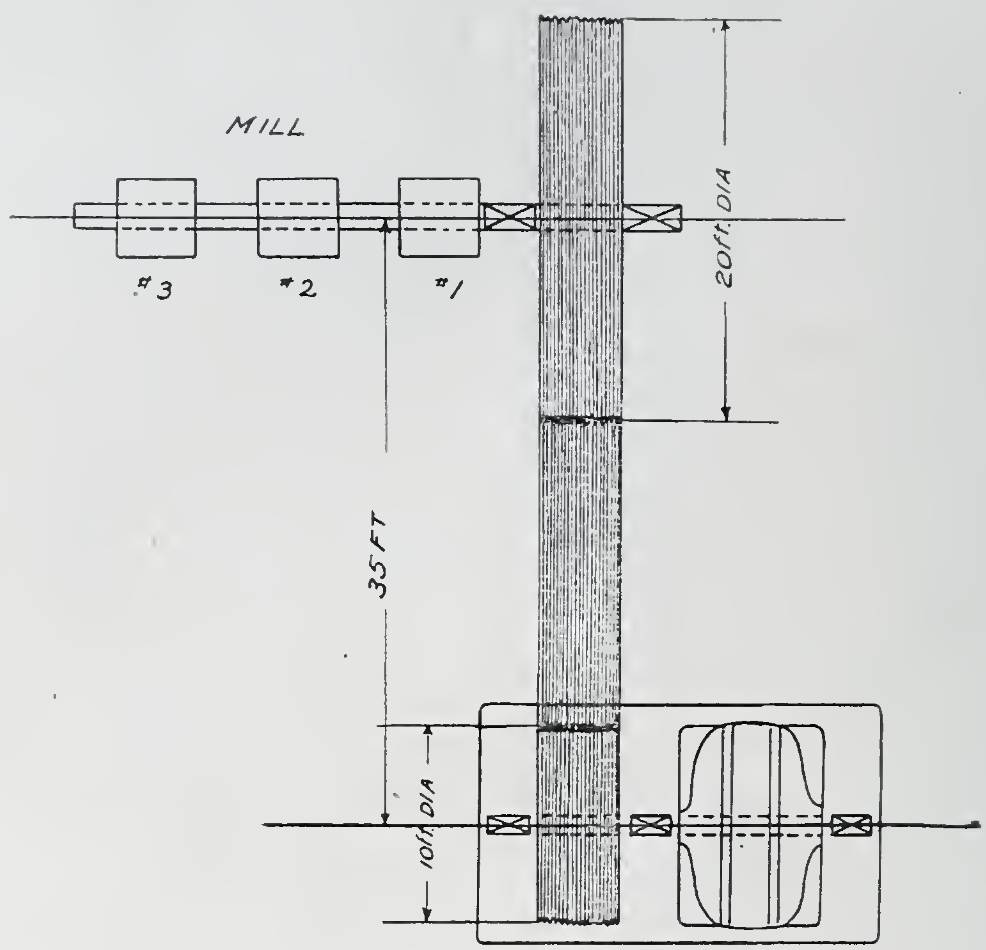


FIG. 15.

In a short paper it is only possible to describe briefly a few installations; and while the generally successful operation of these plants, together with such considerations as reliability, ease of control, increase in output and reduced size of power house required, are conditions which seem to be quite favorable to the adoption of electric drive, it may not in all cases prove economical. Where mills do not have blast furnaces, water or other power, and where coal is fairly cheap, steam power may be more economical on account of the greatly increased cost of electric drive. When cheap power can be obtained from water falls or from blast furnace gas, electric drive

has good chances of proving considerably the more economical, at the same time possessing the many advantages not peculiar to any other form of power.

DISCUSSION.

Mr. Berentsen: I would like to ask Mr. Reed to give some data about the fly-wheels used, as I believe they are the highest-speed wheels ever made for commercial use.

Mr. Reed: These wheels are to be run at a fairly high peripheral speed—I believe about 16,000 ft. per min. There are two 100,000-℔. fly-wheels mounted side by side on the same shaft. The hub is a steel casting upon which is built a sheet steel rim made of No. 22, segmental punchings built overlapping and dovetailed to the arms of the spider. Heavy end plates and through-bolts clamp the punchings tightly together. The friction between punchings alone would be sufficient to withstand the force corresponding to about twice the normal speed of operation. The radius of gyration is about 62 in. and the fly-wheel effect—weight in pounds multiplied by the square of the radius of gyration in feet, equals 2,600,000. This laminated wheel is much safer in operation than a cast steel wheel of same diameter.

Mr. Cronemeyer: I would like to ask Mr. Reed if any attempt has been made to apply 2-phase and 3-phase alternating-current motors directly to the drive of auxiliary machinery. I understand that the starting torque of the alternating-current motor is not as large as that of a direct-current motor. To what is that due? Is that an inherent quality of the induction motor?

Mr. Reed: Alternating-current motors have been used extensively for driving the auxiliary apparatus in mills, but not to such an extent as direct-current motors. A series-wound alternating-current motor has practically the same characteristics and advantages as a series-wound direct-current motor. These motors have been used in street railway work principally, although some have been applied to cranes. The induction motor has frequently been used, operates satis-

factorily and, when properly designed, any desired starting and running torque may be obtained. The characteristics of this motor are frequently compared with those of the direct-current shunt motor, which is not so well suited to crane and similar work as one having the characteristics of series winding. It would probably take more energy to go through a cycle of such operations than would be required by a series-wound direct-current motor. In some cases, however, alternating-current will be cheaper than direct, and all these conditions must be considered in order to determine upon the best installation. There are no special difficulties in applying alternating-current motors to cranes or other mill work and many installations are operating successfully.

Prof. Trinks: I admire electricians because they are so precise and so scientific; they can tell us, within ½ per cent., what the efficiency of an electric motor is. The mechanical engineer looks upon electricity simply as a convenient method of power transmission, comparable to a belt, a rope, or a shaft; but when you ask the mechanical engineer the efficiency of a line shaft, of a rope or a belt drive, you receive the reply: "I don't know." In this, the electrical engineer has a decided advantage; he knows, and tells everybody that his electric motor has an efficiency of probably 85 per cent., and the natural inference is that belts or ropes must have a lower efficiency because nothing is said about them. As a matter of fact, rope drives have about 95 per cent. efficiency, depending upon the number of ropes and the style of drive. It is to be regretted that reliable tests of rope and belt-drive efficiency are so seldom made by manufacturers and transmission engineers. The question of efficiency being decidedly in favor of belts or ropes, it follows that electricity should not be used as the only means of power transmission, but that engineering judgment should be exercised in determining the power to be used.

It must be admitted that electricity excels all other methods of transmission for convenience. An electric cable may be strung where required, and machinery may be arranged in

any position without reference to line shafting. There are instances, however, where rope drive will save both in first cost and in cost of operation, particularly when the process of manufacturing calls for a number of parallel shafts with machines nearly in one plane.

Next comes the question of size of machines; take as an example, our trolley cars. Everybody admits that it would be a mistake to go back to the old cable cars, or to steam-driven cars. Similarly, nobody would advise having the auxiliaries of rolling mills driven by steam. But the driving of large mills is another matter. It appears to me to have a striking resemblance to the installation of large electric hoists for deep mines. A couple of years ago engineers in Germany were extremely enthusiastic on the subject of large electrically-driven hoists. But in the last two years they have gone back to steam. Why? The first report of the superiority of the electric hoist surprised everybody. In some cases half of the original battery of boilers could be shut down. But the reason for this was that these electric hoists replaced steam engines of the most inefficient description.

An advance in one line stirs up the competitor; the engine builders re-designed their machines to effect a saving in steam. They built hoists driven by twin tandem compound condensing engines, with governors and suitable regulating devices to prevent the operating engineer from wasting steam. The result is that the new steam hoists show even better economy than the electric, and save a great deal in first cost. It must be understood, however, that these hoists are large units, probably 4,000 h. p.

The question then arises: Will there be a similar reaction in rolling-mill work? The electric drive of rolls, like the electric drive of hoists, started on the European continent. Electric drives are installed to replace old worn-out steam engines, and of course there is quite a noticeable gain. Besides, the rolling-mill engine has been sadly neglected, particularly the reversing type. All that was expected of it was that it run and never break down, no questions being asked about

steam economy. But times are changing and the builders of rolling-mill engines will have to pay greater attention to steam economies. I fought for reversing-engine economy and made a small beginning with the design of two twin tandem compound reversing engines which I described in a paper before this Society almost three years ago. These engines have now been in operation 2½ years and have been copied extensively; 13 or 14 other engines of this type having been built in this country since then; but I cannot discover any radical improvement in any of the newer engines.

And in regard to tests of these engines; an indicator is attached and the probable steam consumption per i. h. p. hr. is calculated. That is the extent of the test. Boiler feedwater tests are never made because of the work involved. Only three days ago the steam engineer of the company owning the engines mentioned, came to see me. I asked him, "Did you ever carry out that test which you proposed to make?" He replied, "No, we have never had a chance to set aside a separate battery of boilers for one engine." In this the electrical engineer has a decided advantage. He connects a voltmeter and an ampere-meter to his motor, and the story is told. The steam engineer cannot do this, and curves such as shown here tonight will never be obtained by the steam engineer unless new measuring devices are invented.

I do not think that a reversal in four seconds is anything extraordinary. When I read my paper here on compound reversing engines, I was told by a gentleman in the audience that such an engine would never be a success because it would necessarily be sluggish in reversing. To satisfy myself on this point, I observed the behavior of one of the engines with a tachometer and a stop-watch and found that it reversed from 120 r. p. m. forward, to 120 r. p. m. backward, in 1.6 sec.; the engineer told me that he could make the engine reverse even faster than that, but it was unnecessary to do so because the ingot could not be brought back into the rolls in less time. The electric motor will have to pass through a stage of further development to equal or exceed that performance. I

have repeatedly counted 14 seconds between reversals on single-expansion old-type reversing engines which would compare poorly with a modern electric motor reversing in four seconds. From this it will be seen that for large mills the steam engine is not yet obsolete and I am positive that it can yet be improved for reversing mills.

For 3-high and for continuous mills, the electric motor certainly has strong features, making it preferable to the steam engine. But I believe that the future will see an increasing use of the gas engine coupled directly to large rolls. We should be able to design a gas engine for rolling mill work and, for example, connect it to a series of continuous mills by a rope drive. The gas engine should be in a separate house so as to be protected from the dust and cinders of the mill. It seems to be one of the traditions of rolling-mill engineering that the engine must be in the same room with the mill. I have seen many rolling-mill engines where the main bearing cap had just one big hole for a piece of suet, which was the only means of lubrication, and, in case of heating, a stream of water was turned into the bearing. The electrical engineer, observing these conditions, has wisely placed his motor in a separate room, free from dirt and dust. But why can we not do the same with the engine? And why can we not design a gas engine free from that objectionable feature of the present type, viz., that it is very economical at full load, but not much better than a steam engine at half of maximum load? Why do our foremost engine builders insist upon following, absolutely and blindly, the Nurnberg type? I venture to prophesy that the rolling-mill and blowing-engine types of gas engine will gradually leave the beaten path of the Nurnberg engine and will draw closer to the English type of scavenging engine which can be designed to allow of considerable overload. It will mean a considerable saving over the gas-engine drive with interposition of an electric transmission. The gas-engine-electric drive requires the engine, generator, motor, fly-wheel, then another generator, and a motor on the mill shaft; sometimes two or three motors on the mill

shaft. In addition to all of this there is a lot of auxiliary apparatus, such as resistances, circuit breakers. I think the cost of all of this will run very close to three times the cost of a gas-engine and rope drive.

I do not wish to give the impression that I am belittling electric transmission—far be it from me to do so; but I feel that there are limitations to its usefulness, and that we should learn to judge those limitations.

Mr. Reed: For comparatively short distances, at fairly constant torque and speed, and where the ratio of driving to driven shaft speed is comparatively low, a single transmission by gears, ropes or belts has a good efficiency. Under the conditons ordinarily encountered, however, such as variable speed of driven shaft, variable torque and load, large speed reduction, changes in direction or great distance of transmission which would require a number of mechanical transmissions in series, the electric drive is not only more efficient and convenient, but is more easily controlled than other methods, effects a saving in labor and power, and increases the production. In such cases electric transmission should be used, but it should not be assumed to be the best in all cases without consideration of others.

I do not wish it understood that I advocate electric drive in all cases, nor for all reversing or continuous rolls. I stated in my paper that in some cases it may be more economical to use steam engines for direct drive, and that the conditions seem most favorable to steam drive when cheap coal is available. If, however, blast-furnace gas is used and the cost of fuel is practically the cost of installing gas-washing and cleaning apparatus, where over half the available gas is generally waste, then electric drive will, in most cases, be more economical than the steam engine. Again, if power is obtained from water falls or some other fairly cheap source, the electric drive should certainly prove economical. I believe about 45,000 h. p. is to be taken from the surplus blast-furnace gas at Gary and used for driving machinery electrically.

If electric drive procures the design of a better steam engine for this work, it will have accomplished some good results. It seems to me that with steam engines, even of a much higher efficiency, the power could not be produced at the low figure obtained from blast-furnace gas-engine-driven generators, unless very cheap coal is available. Where furnace gas is used for generating steam, the power derived from the steam engine is only about 40 per cent. of that which could be obtained from the same quantity of gas if used in gas engines. This means a great increase in the efficiency of the steam engine to enable it to compete with the gas engine.

It is better to keep electrical machinery as free as possible from dirt, dust, oil and water, and it would probably also be better, as suggested by Prof. Trinks, if steam engines were treated the same way, although the effects upon engines would not be so marked as upon electrical machinery. In reversing-mill drive more than one motor is frequently used in order to reduce the fly-wheel effect, and loss of energy in reversing. As the number of motors is increased, their rating and diameter decrease, so that the total horse-power is the same as that of one large motor having greater fly-wheel effect.

The chances look more favorable for the use of gas-engine-driven rolls, provided the engines can be designed to meet the requirements—large starting torque, and capable of being easily reversed and started under load. I have never seen such an engine as is required in a reversing mill, one whose speed could be controlled as required. In continuous mills, there may be some cases, with coal fuel, where steam-engine-driven rolls are more economical than electric drive; but when it is necessary to transmit the power from any distance or to distribute it over a considerable area, the cost is generally much less with electric transmission.

Mr. Haslam: I would like to ask Mr. Reed why it is, that with all our scientific accuracy, we do not seem to be able to secure from the manufacturers of electric apparatus any idea of the time in which a motor running at full speed in one direction, will reverse to full speed in the opposite direction.

There ought to be some reason for that lack of knowledge. Such information would be very useful to engineers. Mr. Reed made the statement that the gas engine will give 2½ times as much power as a steam engine for the same consumption of coal. I think that is an open question and I would like to have the authority for the assertion.

Mr. Reed: When complete information is available regarding the machinery to be reversed, the time can be calculated closely. My statement was that gas when used in a gas engine will produce 2½ times as much power as can be obtained from the same quantity of gas if used to generate steam and that steam used in a steam engine for mechanical power. My information is from comparisons of steam engine, boiler, and gas engine efficiencies as given in technical literature. I have made no tests.

Prof. Trinks: The maximum thermal efficiency of the steam engine is 20 per cent.; the maximum thermal efficiency of the gas engine is 40 per cent.; their respective average efficiencies are 14 per cent. and 28 per cent.; consequently, the gas engine uses about half the fuel of the steam engine. But the efficiency of the steam boiler being about 70 per cent. makes the ratio of 2½ between gas and steam engines about right.

Mr. Wiley: I would like to ask some of the mechanical engineers about the methods used, or information available, to determine the power of steam engines used in rolling mills.

Mr. Haslam: The practice in rolling-mill work where the steam engine is used is to give the mill all the engine it will take; if they have a bigger engine, naturally they will get more out of it.

Prof. Trinks: The question of power required for rolling has always been enshrouded in a veil of secrecy; rolling mill men have been loath to impart information acquired by experience. In designing rolling-mill engines, I found that lack of this knowledge was general. As a specific case, take an engine to drive an 18-in. mill. The material to be rolled may be soft iron or hard steel—one requiring nearly twice the

power of the other—and may enter the rolls very hot, or rather cold; the draft of the rolls may be light or heavy, and there may be material in only one pass or in two or three at a time. All this makes variations of over 300 per cent. in maximum power required. All this is not considered by the mill man, who merely specifies "an engine for an 18-in. mill." About all that can be done is to take the worst possible case and build an engine that will not be stalled even though the material gets so cold that the rolls or housings are broken. We should have more information on this subject and much credit is due the electrical engineers for their thorough experiments and investigations on similar steam direct-driven mills by means of the continuous indicator. We owe much to the liberal policy of large electrical companies for data published broadcast, and which, I believe, forms the only reliable information published on the subject. Our schools are now taking up the matter, and we hope to have installed, at the Carnegie Technical Schools, a good-sized mill for making investigations along these lines.

Mr. Wiley: I brought this question up to show the attitude that has been taken in some cases, in which the electrical manufacturers are required to guarantee the operation of a system to do a certain work; and to show how much ground has to be covered in giving a guarantee of this kind in view of the small amount of investigation that has been made, and the data available. In other words, in order to get the most satisfactory results, it is necessary to have the best of co-operation between the mechanical engineer, the customer and the electric manufacturer. It is a big problem and, as has already been shown by present installations, the electric drive provides a simple and accurate means of analyzing the actual operating conditions in full detail; this in marked contrast with the approximate method previously employed, where so much depended upon the personal opinion and experience of the engineer.

Mr. Cronemeyer: I want to say, in reply to Prof. Trinks, that there is a movement under way to determine the power

requirements of steel mills on a very large scale. Whether they will be published or not is another question, but by the time these experiments have been completed there will be available, for the parties who have undertaken them, very complete information of just what may be expected under different conditions. A rule quite commonly used, is: "For rolling steel, the requirements are 15 h. p. per in. of width for 25 per cent. reduction and with stock traveling at 100 ft. per min." While at the present time the application of gas engines to reversing-rolls is out of the question, perhaps it is not so much so as appears at first sight. In the year 1900, there appeared in "Engineering" the description of a reversing coupling which employs the coiling effect of a spring similar to the winding of a rope on a drum. The builders claim that they exert a very large torque and at the same time reverse quickly.

Mr. Ellis: Referring to Mr. Haslam's remark as to how we figure engine power on different mills, my opinion is just about the same as his; it is usually the custom to sell just as big an engine as can be put in. We have had pretty nearly the same experience, and after buying motors for rolling mills for about eight years I find that I do not know much about them yet. I do not wish to oppose the motor, but however much you know about motors and however well you can show the curves, the roller may conclude that he is not getting out enough tonnage, will put on a little more draft and increase the load until the mill shuts down. A continuous mill with standard reduction and elongation, such as the rail mill at the Edgar Thomson works, is a different proposition altogether. In that case one can figure pretty closely on what is going to happen. It is claimed that there are gas engines now building that will stand considerable overload, more than the average steam engine. The gas engine suffers the disadvantage of being troublesome to start up if stalled, and it is possible that we will go back to the steam engine.

Mr. Wiley: I do not understand the point Mr. Ellis makes about the overload capacity required in a mill. I think that

in any case a roller can get sufficient draft to injure some part of the equipment. I do not see just where the limiting point is. If the power requirements are large enough something is going to give way.

Mr. Ellis: That is a good question. Suppose I am using a 10-in. by 10-in. ingot, I decide to make a 12-in. ingot but do not want to buy a new mill. Today motors are bought as cheap and as near to the required capacity as possible, but steam engines were never bought as close as that. The result is evident.

Mr. Haslam: I think it would assist the electricians' position if they understood the difference in rolling mill practice between a continuous and a reversing mill. In a continuous mill the ingots are at approximately a uniform heat, the amount of reduction, and consequently the amount of power required, is governed by fixed passes in the rolls, and it is not a very difficult thing to calculate the power required to drive them. The draft in a reversing mill is not fixed and is all in the hands of the roller; the only thing limiting the tonnage is break-down. The mill is built strong enough to break the engine, and the engine strong enough to break the mill.

Mr. Reed: A motor can be made as large as may be necessary, and if it is too small it will fail just as any other drive would do under the same circumstances. If the motor does not take care of the work it is due to a wrong application or insufficient power, rather than to the motor itself. The troubles experienced when motors were first used for driving auxiliary apparatus were largely overcome by making them larger, and heavier mechanically. This experience should be kept in mind in applying motors for driving rolls; it will be more expensive in first cost but cheaper in the end.

Mr. Lyons: In the reversing mill, the screw-man is in complete control. If the piece of steel is at a higher temperature than usual, the rolls will be closed correspondingly, with the result that the mill will be stalled, necessitating reversal to release the steel from the rolls. This is quite easy with a

reversing steam engine and is done very quickly, but with an electric drive, the circuit breaker would be thrown out, requiring some time to adjust or throw in the circuit breakers before the mill could be started.

Mr. Reed: If the rolls are screwed down too much and the motor blocked, automatic circuit breakers will prevent any abnormal overheating or burning out, the circuit being opened just as soon as the danger point is reached. Electric motors will carry the same overloads that steam engines will before being blocked, and can be easily and quickly reversed so that material may be released from the rolls before much cooling takes place. Under these conditions there is no reason whatever for a motor burning out and, with the usual safety devices, it is practically fool-proof.

Mr. Chessrown: Isn't that a case of scientific accuracy? The man made a guess at the mill and said, "We will make it 50 per cent. larger to make it safe," and got something 50 per cent. larger than he guessed he would need. The same is equally true of a motor, simply a question of what you ask for, the result depending upon how accurately the engineers, who ought to have this information, can place their data in our hands. When you buy a motor you say you want a motor to do a certain work, and you want it guaranteed. "How much of a motor do you want?" "I don't know." When you buy an engine, you say you want an engine, and they put it in. "What kind of an engine is it?" "I don't kow, but it is running." That is good scientific information, and is the sort of data from which we ought to design a motor that will do almost anything.

It simply comes back to the fact that the rolling mill people have not taken the pains to secure accurate data on the work they have done. They have put in a mill and they have rolled up to the capacity of the engine. If that engine happens to be 5,000 h. p. and a greater output is desired, a 7,000 h. p. engine is put in and the mill operated up to that capacity. That represents the business of rolling mill development. They made the mill a little heavier, and, in turn, put in a

larger engine. With all that experience we have come into the field with the electric motor and ask for the data which has been obtained from all this long and useful experience. It was necessary for us in some cases to make tests to get the data. As Mr. Reed has said, it is merely a question of knowing what is to be done, and then we can build motors to do that work. It is a question of knowing what you want to do and designing to fit the conditions.

Mr. Wiley: In the hoisting work in which electricity has been superseded by the steam engine, does Prof. Trinks refer to cases in which cheap electric power is available, hydro-electric, for instance?

Prof. Trinks: My remarks referred entirely to coal fuel or coke-oven and blast-furnace gas propositions. For plants located near abundant water power it would be out of the question to use steam because water running down hill is cheaper than anything else.

Mr. Bole: It must be hard for the electrical engineer to obtain the ready prepared data which he would like, for it probably is very scarce. I believe it safe to say that until quite a recent date many a rolling-mill engine has lived its active life without ever having had an indicator applied to it to show what it was doing. Such engines were compared with each other in terms of cylinder diameter, stroke, revolutions and boiler pressure, which while fairly suggestive of the maximum possible power which the engine was capable of exerting, gave little exact knowledge of the actual power being exerted at any less than a slowing-down load. In modern rolling-mill engines, even where the indicator is freely used, its indications must be carefully interpreted, for much of the irregular and intermittent work may remain constant for only a single revolution of the engine. The indicator will of course show a mean effective pressure in the cylinder, which effect is modified by the inertia of the reciprocating parts, the fly-wheel, the speed of revolution at a particular instant of time, et cetera, so that it would be quite a job to accurately interpret all of this into terms of torque at the surface of the roll.

One of the nice things about the use of electric transmission of power is the greater possibility of reading accurately, at any moment, a record of just what is going on, and it is certain that as electric motors are still further employed in such work as this, there will eventually be accumulated a fund of very accurate and very valuable data for the use of future designers.

Mr. Skinner spoke of the indication, by electric meter, of the amount of current flowing in the motor during the act of shearing off a bloom. Even with the electric motor, the maximum torque demanded at the armature rim must depend in great measure upon the size and weight of the fly-wheel with which such shears are usually equipped, but the meter reading would be more accurate than any steam engine indicator card could be, and be read instantaneously.

Mr. Haslam: I think the exception taken to tests is not fair. I think if you will go to any well organized steel works in the country you will find, in the master mechanic's office, pretty carefully figured-out indicator cards showing the performance of the engines doing the different kinds of work. There are some isolated cases where such things are not known.

Mr. Reed: In shearing the bloom by the energy in the fly-wheel, the energy supplied by the motor can be determined by instruments, and that furnished by the wheel can be calculated from the decrease in speed during the process of shearing.

Mr. Cronemeyer: I have made indicator tests of some of the auxiliary engines around the plant and determined exactly the horse-power of each particular engine; but the practical electrical man who ordered a motor would buy one from 25 to 50 per cent. in excess of the indicated power.

Mr. Haslam: There is that point Mr. Reed did not touch upon, the reversing of motors. The old practice was to use the smallest motor that could possibly do the work. Later they used larger motors, and the prevailing practice is to apply not one but two, three or even four, because putting the

same current through two motors will reverse a piece of machinery in much shorter time than the same amount of current through one motor with a power equal to the two.

Mr. Reed: That is quite true, and the principal reason it is done is to reduce the fly-wheel effect of the rotating parts of the motors.

Mr. Blum: Prof. Trinks spoke of the relative efficiency of electric and steam hoists in large units. I would like to ask if he has any data as to the relative efficiency of small units.

Prof. Trinks: Not of the smaller units, because I believe the self-contained engine has the advantage. I believe the advantage of the self-contained engine over the electric transmission begins at about from 1,500 to 2,000 h. p. Anything above that I believe should be direct engine-driven; anything below that should be motor-driven.

Mr. Ellis: The gentleman speaking of a reversing clutch referred to a coiled clutch, I presume, that has been in use probably 15 years. It is used to a very large extent and on very large installations in England, but it is not used in this country very much. It is a very simple affair; it is covered by broad English patents, and is used successfully in England to reverse very large mills, one, of which I have knowledge, being about 30 in. in diameter. It is very well known, has been perfected mechanically, and could be used with a gas engine.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

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REGULAR MEETING,

April 21st, 1908.

President J. K. Lyons

In the Chair.

THE MONONGAHELA RIVER:

SOME OF ITS CHARACTERISTICS AND BRIEF SKETCH OF METHODS UNDERTAKEN FOR THE IMPROVMENT OF ITS NAVIGATION.

By T. P. Roberts,*
Past President.

The Monongahela, with a drainage area of 7391 square miles, unites at Pittsburgh with the Allegheny, draining 11 253 square miles, to form the Ohio with a total of 18 644 square miles drainage area. The figures given are from recent measurements of large U. S. Post Office maps of West Virginia and Maryland, and for Pennsylvania and New York, the official map of the Pennsylvania State Department of Internal Affairs was used. The length of the Monongahela, via the Tygarts Valley is about 235 miles, and via the Cheat river to its head-waters it is about 240 miles. Its source on the Cheat is two degrees exactly south of Pittsburgh.

The characteristics of the Monongahela are radically different from those of the Allegheny, the former, for many miles above its mouth, flowing northward upon a bed slope averag-

* United States Engineers Office.

ing, for nearly 70 miles above Pittsburgh, not more than 8½ in. per mile, whereas the bed of the Allegheny slopes from the northeast, for fully 125 miles above its mouth, at an average rate of 2.2 ft. per mile, or about three times the rate of the Monongahela. The Ohio continues with approximately the slope of the Allegheny for 30 miles below Pittsburgh, so that the Monongahela presents the very unusual case of a large tributary with much less fall per mile than that of the main stream into which it discharges. Backwater effects from floods in the Allegheny are sometimes observed at Lock No. 4, 41 miles above Pittsburgh, while Dams No. 1 and 2 are frequently drowned out by Allegheny freshets. Upon several occasions, for brief periods, Allegheny river water has flowed up the Monongahela passing the crest of Dam No. 1 with an upstream current and enabling boats to pass the locks with all the gates latched to the walls. Steamers frequently pass in both directions over Dam No. 1 when the fall at that place may be over a foot.

The Allegheny and Ohio rivers abound with rapids and islands, and both have glacial drift beds of gravel and boulders. The Monongahela, in its 90 miles within the limits of Pennsylvania, has no islands or bars dividing its channel. Its bed is mostly of a compact formation of native gravel and fine sand two to three feet thick, overlying a similar formation of softer material extending to the rock, which is very easily eroded when exposed to the current. After being disturbed by dredging operations, however, and given a rest of two or three years, the hard or "bone" bed is again formed, the result, evidently, of a cementitious process. The elements for this are probably lime and silica, and in late years have possibly been made more active as reagents by the large quantities of iron oxides and acids entering the river from coal mines and manufacturing establishments. Much could be said in regard to the effect of these waste products of the mills vitiating the water for boiler use. The amount of muriatic and sulphuric acid during low-water periods is sometimes as much as ten free grains to the gallon. In 1904 the acid conditions were

intolerable, and steamers passed Lock No. 1 with barges of Allegheny river water from which to make steam. The recurrence of another low-water year is only needed for a greater stirring-up of interest in this serious pollution of the river.

Rock ledges extending into the river more than 50 ft. from the foot of the clay banks are found at but few points, and at no place below the West Virginia state line does a rock bed extend entirely across the river. The mean width of the river at the present pool level is rather more than 900 ft. as far as McKeesport, situated 15 miles above its mouth, where the Youghiogheny, the first important tributary, empties into it. Above McKeesport, to the mouth of the Cheat river, 87.5 miles above Pittsburgh, the width diminishes gradually from about 750 to 550 ft. Above the Cheat, the width again narrows from 550 to 420 ft. at the junction of the Tygarts Valley and the West Fork rivers, West Virginia, which two streams form the Monongahela, 128.5 miles above Pittsburgh. On the whole, the river is easy for navigation, having ample width for steamboats with fleets, or so-called "tows," to pass each other with large margins for safety, and averaging a somewhat greater width than when first surveyed in 1833. This widening of the stream is without doubt due to the wave action of steamers undermining the clay banks, causing them to cave in. In the lower reaches of the river the caving of the banks has practically ceased, many miles of the banks being now prevented from further erosion by almost vertical walls of slag or other protection.

It is sometimes stated that the reduction of current velocities caused by fixed dams must tend to the deposition of silt and the gradual filling of the pools. So long, however, as the suspended load of silt is not beyond the carrying capacity of the higher floods on the improved rivers, no permanent filling of the main channel will take place, and the carrying capacity of the Monongahela floods is more than ample to prevent a general deposit of silt in its channel. There are some landings which require scraping occasionally, and old shallows at the heads of pools have been deepened by dredging. It is true

also, that the approaches to a number of the locks must be dredged from time to time to remove deposits caught by the eddies created by the lock walls. In this connection, it may be stated that no extensive growth of bars at the mouths of creeks is observable along the Monongahela, except at Turtle creek in Pool No. 2. This creek, since the construction of factories and the opening of mines along its course, puts out into the river from 5000 to 15 000 cu. yd. of ashes and mine wastes annually, which material heretofore has been removed by the United States Government. Such disregard of the rights of the users of our waterways will soon, however, be a thing of the past.

THE WATER SUPPLY.

In ordinary years there is an ample water supply on the Monongahela for the existing traffic, which amounts to about 11 000 000 tons per annum. The new pair of locks at Dam No. 2, several miles below the Youghiogheny, each measure 360 ft. usable length by 56 ft. width. The area between gates, however, is 395 by 56 ft., which multiplied by the usual low-water lift of 7.8 ft. and by 40 lockages daily, (a number which may be taken as an average), represents a demand of approximately 80 cu. ft. per sec. for lockages alone. The "flooding" of descending loaded craft out of the chambers, gate valve and dam leakage, is perhaps equal to 20 lockages daily, so that it may be said, to meet the demands of the existing traffic at the lower end of the river requires a supply of 120 cu. ft. per sec.

The small low-water discharge of the Monongahela was always a matter of much concern with the managers of the company which built the first locks and dams. Mr. W. Milnor Roberts, the company's first engineer, on September 19, 1838, reported the discharge at the Brownsville bar, 57 miles above Pittsburgh, to be 75 cu. ft. per sec. In October, 1856, President Moorhead reported it to be 25 cu. ft. per sec. below Dam No. 4, 40 miles above Pittsburgh, and a few days later it was carefully gaged at Brownsville by Mr. Charles Stewart, the company's engineer, and reported to be 23 cu. ft. per sec. No

other actual gagings of the river are mentioned in the reports of the navigation company until 1895 (without doubt the driest season in this portion of the United States since 1879). In that year the discharge at Dam No. 1 was found by the writer to be 166 cu. ft. per sec. The reports of the navigation company show that owing to insufficiency of water during the summer and fall months of the years 1854, 1856, 1863 and 1879, navigation was, for several months, either totally suspended or restricted to vessels of the lightest draft. Usually, however, some kind of traffic could be maintained by drawing upon Pools No. 5 and 6 to sustain the navigation below Dam No. 5. In recent decades the seasons have been more propitious, for, with a largely increased business below Dam No. 5, there has been but little necessity for drawing upon the upper pools to sustain navigation, though some times the permissible draft for boats has been reduced to 4½ ft. in Pool No. 3. During the summer and fall since 1893, flashboards, 30 in. high, have usually been maintained on Dams No. 1 to 4, inclusive, which, when carefully caulked with straw and ashes, tend to prolong the decline of the pools to the permanent crests of the dams. Pools No. 1 and 2, have seldom declined below the tops of the flashboards; but at No. 3 and 4 the flashboard storage has been repeatedly consumed, and at No. 3, in 1895, the level declined to 13 in. below the crest of the permanent dam, and in that year, and again in 1904, it became necessary to draw upon the uppermost pools to assist the navigation below Lock No. 4.

It is to be observed that the 166 second-feet discharge for 1895 included the Youghiogheny. It is quite evident that with a recurrence of such seasons as those of 1838, 1854, 1856, 1879 and 1895, the discharge above Dam No. 3, thought to be only about 75 cu. ft. per sec., would be insufficient to supply the losses due to evaporation on the 15 square miles of pool surface, to say nothing of lockages. Evaporation, under some conditions, on such an extensive surface would amount to more than 100 cu. ft. per sec. The difficulty is fortunately of such nature that a remedy can be applied by building several

auxiliary dams without locks on the Cheat or West Fork rivers to hold water in reserve.

Should occasion demand, in advance of the construction of such extra dams, a supply for the needs of the coal trade can be obtained by drawing upon the upper pools, as has been done in the past. With any considerable increase in the traffic at the upper end of the river such expedient is not, however, to be thought of.

ICE.

It is a remarkable fact that considerably more than twice the extreme low-water discharge of the river in the vicinity of Pittsburgh is daily pumped from it and returned after it has done duty in condensing steam and cooling furnaces. This water is returned at a high average temperature.

Upon one occasion during comparatively low water in mid-winter, when ice 5 in. thick was formed in places on the upper pools, the writer recorded the temperature of Pool No. 1, taking 75 well-distributed points in mid-river, and found the surface temperature to range between 45 and 90 deg. fahr.

Under low-water conditions in winter, ice could not, of course, form in Pool No. 1, while at higher stages the currents interfere greatly with its formation. On Pools No. 2, 3, 4 and 5, however, within the field of active mining operations, ice sometimes forms to the thickness of a foot or more but is kept broken up in such manner as to permit of navigation. With persistent zero weather, however, the broken ice freezes solidly excepting along a narrow channel, generally less than 100 ft. wide, kept open by steamers, and in which they back up or down stream, as the case may be, pulling their boats behind them in single file and making curves precisely as do railway trains. Backing slowly in this manner against the ice, the wheel causes the cakes to sink and to reappear at the end of the train of boats, perhaps more than a thousand feet distant from the steamer's wheel. To see horses and sleighs on the ice in mid-river, closely paralleling the movement of such a

train of boats, is a scene sometimes to be witnessed on the Monongahela.

The chief difficulty from ice is usually felt at the locks by steamers pushing it ahead of their barges into the chambers, filling them so completely that one or more separate lockages of ice must be made before the fleets can enter. Packed ice frequently makes it very difficult to open the lower gates, but the gates once opened a foot or two, the lockmen push it through the opening with hooks and poles until gradually the gates can be pulled farther back. The last operation of freeing the gates of ice is curious. It consists in waving or swaying the gates back and forth on an arc of 10 to 20 deg. as rapidly as the operating machinery will admit of, with the result of generating a suction or drawing current which carries every trace of the ice or drift around the end of the toe post, whence it floats harmlessly away. But for this operation, much valuable time would be sometimes lost in passing vessels. The same movement of the gates is frequently resorted to to free the locks of drift.

OPERATIONS OF THE OLD NAVIGATION COMPANY.

The engineering history of the Monongahela Navigation Company has never been written. If compiled, however, it would prove an interesting and instructive contribution to our knowledge of river hydraulics; the field where nature and the books are at constant loggerheads, and the school where even the ablest engineers never obtain the degree of A. M.

With the navigation company making its surveys in 1838 and commencing its works of construction in 1839, when Western Pennsylvania was little better than a wilderness, it is a story of a private company, poor in money, but with inexhaustible pluck. The engineer and the chief contractor, General James K. Moorhead, in later years chairman of the Committee of Ways and Means of Congress, had had considerable experience in State works on canal and river improvements, and was soon called upon to accept the presidency of the company.

Locks and Dams No. 1 and 2 were put in operation early in 1841; No. 3 and 4, which extended the slackwater to Brownsville, 57 miles, were completed in 1844. Mr. Roberts, the company's first engineer, says, in his personal memoirs, that when meeting General Moorhead to be introduced, the general was standing in water up to his neck, which was the limit, he said, he would permit any river to get the better of him, even on jobs where other contractors were totally submerged.

In 1833 the United States engineers made a survey of the river between Brownsville and Pittsburgh, and proposed dams of 4 ft. lift, so as to impose as little restriction as possible on the movement of rafts, the raftsmen being particularly hostile to any improvement. The navigation company succeeded, only with the greatest difficulty, in having the State permit the lift at the dams to be made 8 ft. Brownsville being at the river crossing of the great national road, with stage-coaches and Conestoga wagons in a constant stream passing westward via Wheeling into Ohio, her citizens looked upon the improvement as promising to establish the head of navigation at that bustling center forever, and some merchants in Pittsburgh actually sold their properties and moved their quarters to "the coming metropolis of the Ohio valley."

A breach in Dam No. 1 occurred in 1843, the scour reaching to a depth of 40 ft. At later periods breaches occurred at Dams No. 2 (twice), 3, 6, and lastly, in January, 1881, for a second time at No. 1, adjoining the section carried out in 1843. These breaches in the dams were, with one exception, caused by the wearing and tearing action of ice cutting down the apex and eventually the bodies or crib structure of the dams.

The writer, by invitation of President Moorhead, inspected the breach of 1881 at Dam No. 1, at Pittsburgh. Its width was about 140 ft. and the scour had extended to a depth of more than 40 ft. below the crest of the dam to the rock, about 25 ft. below the foundation of the crib structure. All of the gaps in the Monongahela dams were successfully closed by floating into them crib "keystones," so to speak, of full dam

size, sinking, filling, and sheeting them with the utmost speed. This was done at No. 1 in 1881 in freezing weather and with the river at a stage two or three feet above low-water level. Although but a few hours' time was permitted for the work, the dam was filled and sheeted before the pool filled up and overflowed the dam. Most engineers would have proposed temporary V-dams above such large gaps. The work was planned and executed by Mr. Thomas McGowan, the company's old and experienced superintendent of repairs, who was in the company's service, in various positions, for 53 years.

The old dams were all built on the gravel river bed with little attempt at dredging. In the course of time they settled, some of them in places as much as four feet. The settlement, however, was cared for as the South sea coral reefs grow, by building up on top. During the past ten years the dams at the lower end of the river have required no raising to hold them at their original elevation, indicating that settlement has ceased.

The ordinary scour below the dams varies from 25 to 35 ft. depth, forming a trough in the river bed from lock wall to abutment shore, and the line of maximum depth being about 150 ft. below the dam. The large stones washed out by erosion makes a shoal reef across the river at about 250 ft. below the dams. Immediately under the eaves of the lower slope of the dams the depth is usually 4 to 5 ft. at pool level, increasing rapidly downstream to the trough. Next to the lock walls and the dam abutment, however, the scour, if left to proceed, would undermine the walls, and even the dam itself, owing to a boring current developed in some way by the frictional resistance of the walls, and it was early found necessary to protect the corners at the ends of the dams with cribs. Sometimes three parallel submerged cribs, each 20 ft. wide, were built outside the lock walls to keep them from being undermined.

To have built the locks and dams on the lines of modern practice with deep foundations would have been "financially impossible" in 1840. Rock bottom for the original four locks

was found only at No. 1, but was found for No. 6, built in 1856, and No. 7, built in 1883. The other locks were built upon hewed timbers laid down on the gravel like railroad ties, with a space of about 10 in. between timbers. The second lock at No. 4, however, built in 1885, has a close timber bottom in a single course. On these timbers a course of 3 in. oak plank was spiked, followed by a second course, 2 in. thick. Evidently no fears of upward pressure were entertained in the event of leaks communicating beneath the floors between parallel locks with one in use and the other pumped out for repairs. Under some circumstances such pressures might be 1½ tons per sq. ft. Nothing of the sort ever actually occurred excepting on one occasion at No. 3, when the floor in one lock bulged up 9 in. while being pumped out. Several thousand tons of large dimension stones were piled in pyramids on the floor, after which numerous holes were cut in the bottom, piles driven, and wrought iron spiders used to tie the floor to the piles.

The experience of the navigation company furnishes something of an argument for developing companies to build at first as best they can within their means, and then rebuild, when necessary, out of surplus earnings. This was the general policy of the old navigation company, which never burdened the wires with quotations of its stocks and bonds. Perhaps not in the history of the country has so small an investment of capital brought about, directly and indirectly, such a growth of population and wealth as resulted from the capital expended in the construction of the locks and dams on the Monongahela, and which has made Pittsburgh a household word, from the Allegheny mountains to the Gulf of Mexico.

It is well, however, that the Government acquired this property in 1897. Since that date the traffic, especially the local traffic, has about doubled, and so many questions relating to jurisdiction, care and management of navigable rivers under national legislation have arisen, that a private company, in control of locks and exacting tolls, would occupy a very peculiar position. This is not to say, however, that the gen-

eral Government in any way discourages states or chartered companies engaging in the betterment of the navigation of rivers, but, of course, the Government, in such cases, reserves the right of dispossession in condemnation proceedings.

Since the United States purchased the locks and dams of the Monongahela Navigation Company, it has entered upon a project of enlargement of the old locks and extension of the slackwater system into the West Virginia coal fields, and has advanced greatly with the work. Until the new locks, about to be undertaken at Brownsville to replace the old, small, single Lock No. 5, are completed, no safe judgment can be passed upon the value of the new locks already completed above that place. The reason for this is that the existing depth (about 5 ft. above No. 5) is inadequate to the demands of miners and shippers. The works in progress and completed up to No. 6 are intended to provide a minimum depth of 8 ft. on the sills and for most of the year, by means of adjustable tops on the new dams, the safe navigable depth will be rather more than 10 ft.

The writer will take this occasion to express the opinion that, on our western rivers, the fleet-towing business will be better satisfied with 9 ft. depth on sills and 8 ft. draft for boats and barges than with any other depth. This opinion is based upon facts relating to the cross currents found on many shoals and bars on the Ohio, and the enormous expenditure of power required to steer great fleets safely through them. The steering is done by backing the steamer's wheel, directing a powerful current against the row of balanced rudders beneath the steamer which thence becomes a lever operating at a point often 500 ft. or more distant from the center of gravity of the fleet. Thus 50 000 tons of freight moving in a given direction can be considerably checked in its motion in the course of a few minutes and turned, if needs be, 30 or 40 deg. in another direction. This control of the direction of motion, which is an absolute necessity for fleets on rivers of comparatively shallow depth and abounding with hard bends and islands which divide the currents, etc., is not practicable unless there is a

margin of depth beneath the boats where the currents may expend their energies. A great fleet a thousand feet long, hugging the bottom closely, is about the same thing as a dike and unless the side pressures exerted against such a moving fleet, developed by the currents, can find at least considerable relief beneath the boats, safe steering is impossible. Therefore, for increase of traffic in the future we need not look to greater draft for the vessels. The writer is of the belief that with a perfected system of locks and dams, and taking into consideration the possibilities of up-stream traffic, the tendency will be towards smaller but more numerous fleets.

Calculations have been made covering the points here referred to, and it appears to be demonstrated that, with an improved river, freight can be moved in large volume, with less capital invested in boats than is now required on the Ohio. We may expect, therefore, a lowering of freight rates on a river where the cost of transporting cargoes in fleets of barges is already lower than it now is with single 12 000-ton steamers on the Great lakes.

NEW WORK ON THE MONONGAHELA.

New locks and dams have been constructed on the Monongahela during the past seven years as follows:

Dam No. 2 and pair of locks opposite the Carnegie steel works at Braddock, about a half mile below old No. 2, at the point where General Braddock's army forded the river July 9, 1755, and where he was most ignominously defeated by the French and Indians from Fort Duquesne.

Dam No. 3 and pair of locks at Elizabeth, Pa., about one mile below old Lock No. 3.

Locks and dams No. 10, 11, 12, 13, 14, and 15 between Morgantown and Fairmont, W. Va. These works, with the exception of No. 10, were completed, for the most part, under the direction of Major Wm. L. Sibert, Corps of Engineers, U. S. A.

Means have been provided for, and, under the direction of Major H. C. Newcomer, Corps of Engineers, U. S. A., work

ELEMENTS OF LOCKS AND DAMS, MONONGAHELA RIVER

CHARACTERISTICS	LOCK NUMBERS 1	2	3 OLD	3 NEW	4	5	6	7	8	9	10	11	12	13	14	15
Distance from mouth, miles	195	11.20	25.0	23.8	41.24	58.92	6867	8274	8755	93.3	1026	104.95	109.85	111.80	11550	124.10
When built {first lock / second lock}	1841 1848	1841 1853-4	1844 1883	1906-7	1844 1886	1856	1856	1883	1882-9	1874-9	1897-03	1901-3	1901-3	1901-3	1901-3	1901-3
When re-built		1904-5														
LOCK Size, feet	50X158 56X216	56X360 56X360	50X158 56X277	56X360 56X360	50X158 56X277	50X165.5	50X165.4	50X159	50X161.6	50X160	56X182	56X182	56X182	56X182	56X182	56X182
Lift at low water	(1) 4.4	7.8	7.44	84	1115	10.93	13.3	9.2	10.6	12.35	1067	10.67	10.67	10.67	10.67	10.67
Depth on lower sill, feet	9.3	8.68		8.42	5.87	5.2	5.5	6.61	5.2	5.5	70	7.0	7.0	70	70	7.0
Guard	10.3	12.3	10.0	121	88	105	96	9.2	10.2	7.6	8.5	7.7	8.0	8.0	80	80
Elevation, upper sill	696.7 695.2	706.6 (2)	716.3	715.25	719.78 726.18	741.31	753.57	763.84	7750	787.0	796.58	807.25	817.92	828.59	839.25	849.92
" lower "	695.6 693.7	698.7 (3)	709.46	707.08	718.38 718.03	730.28	741.36	754.19	7650	775.55	786.92	797.59	808.25	818.92	829.58	840.25
Founded on	Rock	Piles in Gravel	Gravel	Rock	Gravel	Gravel	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock
Walls-height above floor	23.3 24.2	2977	23.8 24.1	31.5	25.4 25.8	26.6	29.4	260	36.0	275	275	26.5	27.0	27.0	270	270
" base width	12.0	River Wall (4) 16.4	12.0 14.0	16-20-22	12.0 15.0	140	14.0	14.5	18.0	11.6	160	14&15	14&15	14&15	14&15	14&15
Upper guide wall-length	300	105	789	360	890	None	None	34	190	130	180.2	100.3	100	None	100	997
Lower " " "	320	300	275	360	310	118	120	85	107	175	1556	152	523	1517	152	117
Upper guard wall "	195	150	225	150	166	108	130	238	107	65	533	912	66	91	90	91
Lower " " "	None	None	None	None	None	None	None	None	None	None	52.5	None	None	None	None	53
DAM Length, feet	962.5	808	689	684.36	703	620	626	525.5	600	410	445	500	447	425	433	420
Material	Timber stone filled	Concrete on piles	Timber stone filled	Concrete on piles	Timber stone filled	Timber stone filled	Timber stone filled	Timber stone filled	Timber stone filled	Masonry	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete
Elev. of crest and pool	707.4	715.25	723.1	723.9	734.98	746.41	760.15	7700	780.8	793.4	804.66	815.33	826	836.67	847.33	858.0
Founded on	Gravel	Piles in Gravel	Gravel	Piles in Grav&Sd	Gravel	Gravel	Gravel	Gravel	Gravel	Rock	Rock	Rock	Rock	Rock	Rock	Rock
Fall over at epoch of submergence of lock walls	(5) 0 to 4 ft.	3.0	1.9		2.7	3.2	57	48	5.5	96	70	8.9	8.4	93	85	71
Length of pool, miles	9.25	12.6	16.24	17.44	17.68	975	1407	481	5.75	93	2.35	49	1.95	37	86	
ABUTMENT Type	Crib	Concrete vert face	Crib vert. face	Concrete vert face	Concrete sloped	Crib vert face	Crib vert face	Masonry sloped	Masonry	Masonry sloped	Concrete sloped	Concrete sloped	Timber vert face	Concrete sloped	Concrete sloped	Masonry vert face
Founded on	Gravel	Piles in Gravel	Gravel	Piles in Grav&Sd	Gravel	Gravel	Gravel	Hardpan	Rock	Rock	Rock	Rock	Rock	Rock	Rock	Rock

(1) About pool full Davis Island Dam (2) Upper guard sill 707.1 (3) Lower guard sill 699.25 (4) Middle wall 20' (5) Dependent on stage of Allegheny River

has been commenced in the construction of a new dam and pair of locks at Brownsville, Pa., to take the place of old Lock No. 5, 1¼ miles above the new dam.

The principal dimensions of all the locks on the river, including elevations, lift and length of pools may be referred to in table No. 1.

The new locks and dams are of concrete. At No. 2 all of the work rests on piles driven 3 to 4 ft. apart, which, after being cut off to prescribed elevations, were notched and their tops enveloped in the concrete. About 5600 piles were used in the work. The floor of the chamber is 5½ ft. thick, resting on piles. In all, about 40 000 cubic yards of concrete were used at No. 2 in the construction of the locks proper, which work was let to the Dravo Contracting Co., of Pittsburgh. Work on the dam, abutment, erection of lock gates, power house installation, and gate machinery was done by hired labor, and the total cost was about $650 000. The lock walls were built in monoliths 25 to 30 ft. long and containing from 400 to 500 cu. yd. each; with but few exceptions, from time of start to finish, these were completed in from 24 to 30 hours.

The lock gates are of steel, with horizontal beams and riveted plate sheeting. Compressed air is used for operating the gates and capstans. The valves through which the locks are filled and emptied were designed to be worked by hand, but plans are about ready to enable them to be operated by power. The valves are vertical butterflies, the discharging valves, two for each chamber, being 7 by 8 ft. each.

ADJUSTABLE TOPS ON DAMS.

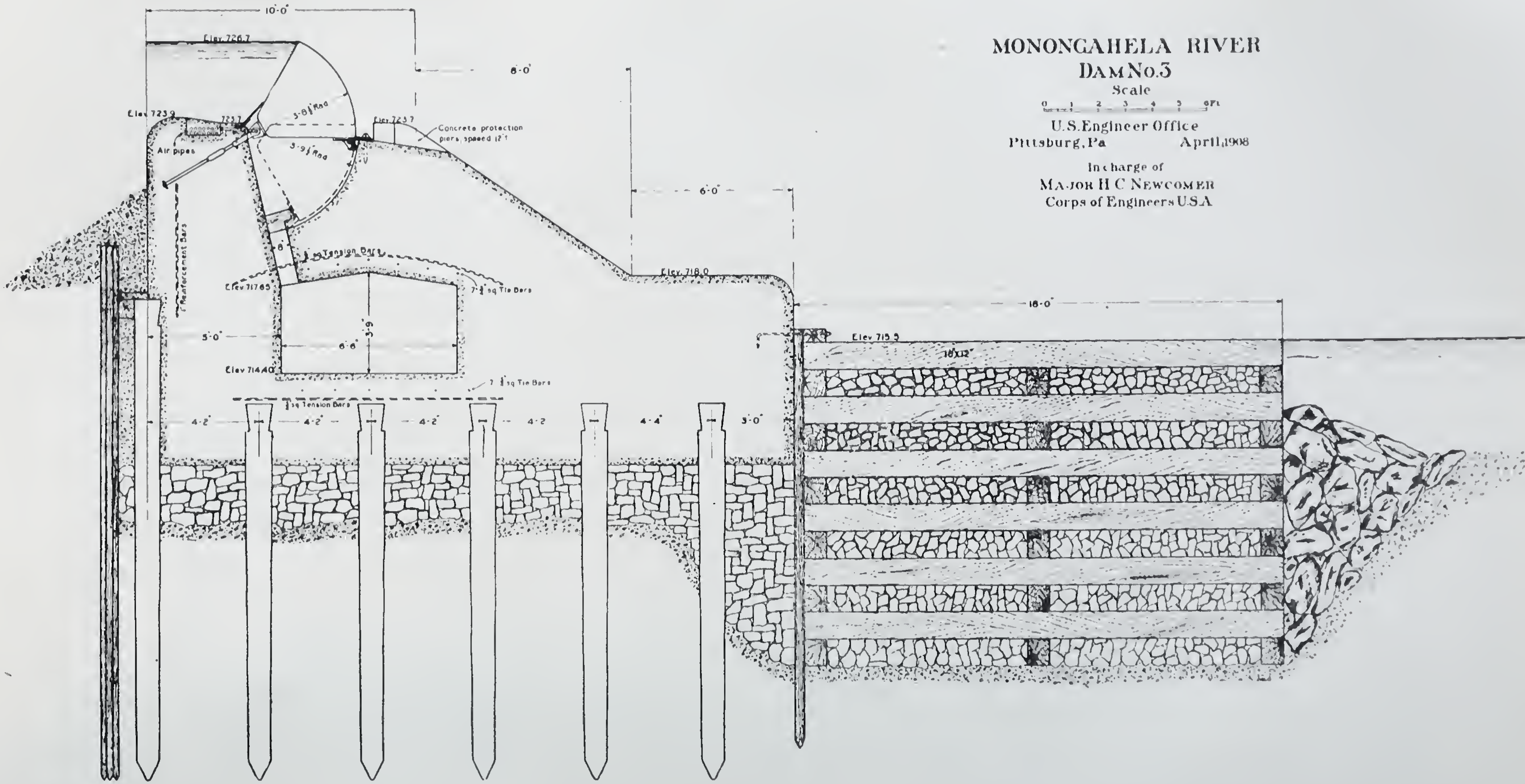
Dam No. 2 is provided with an adjustable top of steel drums, in sections each about 38½ ft. long and having a lift of 3 ft. There are 20 of these drums on the dam, and for Dam No. 3 similar drums have been made, awaiting low water to be put in place.

In operation, after the water in the drums is expelled by compressed air, operated by valves from the lock wall, they are raised to the limit of their lift by hydrostatic pressure com-

municated from the upper pool through a conduit in the dam as shown in the sectional drawing. A pier in mid-river divides the dams into two nearly equal sections. At No. 2 the sections are nearly 400 ft. long, requiring ten drums each. Cylindrical valves supply water to the conduits and are placed as follows: One in the lock wall, two in the middle pier, and one in the dam abutment.

This type of adjustable dam is known among army engineers as the Chittenden drum weir. For various reasons its value in actual service, on rivers subject to ice and drift-bearing floods, has not as yet been satisfactorily demonstrated. Any reasonable desired strength can be given its parts without detriment to the principles of its operation which is so simple as to be peculiarly attractive.

For several months after the placing of the drums on Dam No. 2, in 1906, they were in operation holding the pool 3 ft. above normal level for weeks at a time, requiring the use of air occasionally only, to expel the water from them. It was observed by the writer that they would stand up longer in alignment and elevation with six or more inches flowing over their tops than when such depth of natural overflow happened to be three or four inches. The conclusion was reached that, with the greater depth and higher velocity of the water falling over the drums and past the row of blow holes, a suction was developed which prevented the water backing through the holes into the drums. With a less depth, the water, upon striking the concrete, was so splashed or churned as to be easily deflected into the holes, gradually filling the drums and causing them to partially sink. This is a difficulty which can be remedied by shields on the ends of properly disposed drain pipes connecting with or opposite the blow holes. On repeated occasions the drums were lowered and raised in from two to four minutes against a head somewhat greater than their lift. Against 2½ feet head they sometimes rose almost simultaneously with such force and suddenness as to send a low but well defined wave up the river hundreds of yards.



MONONGAHELA RIVER
DAM No. 3
Scale
0 1 2 3 4 5 6 Ft
U.S. Engineer Office
Pittsburg, Pa April, 1908
In charge of
MAJOR H C NEWCOMER
Corps of Engineers U.S.A.

A principal source of trouble with them arose from the steel plate flappers or water seals along the hinge line or axis of their movement, which, not always keeping close contact with the drums, made it possible for light drift to work its way down into the conduits below them.

After the first winter's freshets had passed it was discovered that the conduits were so choked at the outlets that the butterfly valves could not be turned to permit the drift to escape. Had the valves been of a lifting type, affording a free discharge of full conduit size, this difficulty might not have arisen. There had also been some damage done to the flappers which may have contributed to the trouble. Throughout the season last year, the water was so high that there was no necessity for raising the drums, and unfortunately too high for men to enter the conduit and clear the valves.

Doubts are entertained by some engineers regarding the practicability of securing a reliable water seal along the axis of the drums, and in securing sufficient water-tightness along their down-stream edge, that is to say, tightness against leakage from the conduits with loss of effective head.

From what has been said regarding the discharge of the Monongahela in dry seasons, it is manifest that at times there is no water to spare for any kind of adjustable dam not almost absolutely water tight. In this connection it can be said that it was fully realized there were difficulties presented by this type of dam on rivers subject to such abnormally small discharge as sometimes occurs on the Monongahela. It was therefore contemplated, during very low water periods, to prop the drums temporarily, close the conduit filling valves and, if necessary, stop flapper leakage with ashes so that in no event would the drums, after storing up water, proceed to drain it away uselessly.

For the purpose of removing accumulations of ice or drift interfering with the operations of the locks, the currents induced by the sudden lowering of the dams as much as three feet would be considerable advantage at times. It is claimed for the drums also that they can be operated with less danger

to the employees than would be the case with methods necessitating the use of maneuvering boats.

STREAM SLOPE AS AFFECTING HEIGHT OF DAMS AND LOCK WALLS.

In the table giving the elements of the locks and dams, it will be observed that at the period at which the lock walls are submerged, the fall at the dams in West Virginia where the maximum bed slope is found, is about three times that observed at the dams on the flatter portions of the river.

For lack of examples with a considerable number of dams in a series on streams of greatly varying slope and considerable range of discharge, some mistakes have been made by lock builders in the past. Thus at No. 7, built in 1883, the lock walls are submerged about three feet, and the locks are incapacitated for use while the locks next above and below may still show out of water, yet the guard (height of walls above crest of dam) at No. 6 is only about four inches greater than that at No. 7. To a less extent, No. 9 Lock walls. built in 1875, are also subject to too early submergence, although about 12 or 15 years ago they were raised 2 ft. higher than as originally built, but they are yet nearly 2 ft. too low.

It was thought at one time that, by remodeling the abutment of Lock No. 7 and slightly lengthening the dam, some improvement would result, but no material benefit was derived from the work which was done.

The irregularities referred to are thought, by the writer, to be due to variation in the velocities of the currents corresponding with difference of slopes. Pool No. 7 is five miles long while No. 6 pool, below it, is over 13 miles long. It is plain that the high velocity water striking the flatter slope below No. 7, where its velocity is diminished, must proceed to accumulate a head sufficient to do its work. The same is true with dams of equal height, where much greater heads are developed to overcome the obstruction they make with high than with low flood velocities. Hence, unless the banks admit of it, the permissible lift of dams diminishes as they are built

nearer to the headwaters where the declivities are usually greater.

Not so easily to be explained is the case at Lock No. 9 where, very strangely, there is little difference in the fall at the dam from low water up to depths of six to seven feet flowing over it. In consequence of this peculiarity the pressure against the lock walls in locking operations during high stages resulted in a deflection of the river wall of 4½ in. each time the locks were filled. The walls would straighten up when the lock was emptied. Here was a case of masonry work almost as flexible as were the concrete trolley poles referred to by speakers in our Society a few years ago. I will add that the suspicious conduct of the wall at No. 9 was cured by the addition of several feet of concrete applied to its exterior face.

To add to the mystery of the abnormal lift at No. 9, in high navigable stages, it should be remembered that the Cheat river, by many persons considered to be the real father of the Monongahela, enters Pool No. 8 only about three miles below Dam No. 9.

The Mississippi backs up the Ohio, and vice versa; so with the Allegheny and Monongahela; so also does the Youghiogheny back up the Monongahela and vice versa; but the Cheat, for reasons known only to itself, but rarely indeed backs up its twin brother to any noticeable extent. Perhaps it acts in this manner out of regard to the value of the water power in the West Virginia streams. It must be true that many useful things are left to be discovered by the rising generation of engineers.

In closing this desultory paper a few words may not be out of place regarding the afforesting and storage reservoir projects now engaging so much attention. The U. S. geological and topographical surveys of the Monongahela basin are practically completed, and the results are used as a model to be reached, it is hoped, with the same perfection upon the other basins tributary to the Ohio.

By authority of the War Department, Major H. C. Newcomer, in charge of river improvements in this engineering dis-

trict which embraces the Ohio and its tributaries above the Pennsylvania state line, has, for several weeks past, had assistants at work on the compilation of river gage records at Pittsburgh. Daily records are complete back to 1872, and prior to that are more or less complete to 1855. A curve for the mean discharge of the Ohio immediately below Davis Island Dam has been prepared from a large number of current meter observations, so that, for the first time, the monthly and annual discharge of the Ohio at Pittsburgh, and percentage of run-off of rainfall in the basin above the city will shortly be available for study. Hydrographs have also been made covering the daily depths, for many years past, in the Monongahela at Lock No. 4, in the Allegheny at Freeport, 28 miles above the city, and at Pittsburgh.

In connection with the conservation of the resources of the United States, a subject which President Roosevelt has so earnestly pressed upon the attention of Congress and the people generally, Major Newcomer has been directed to report upon the value of water power of the 24 Government dams already built in the Pittsburgh district. The work of the National Government along the lines indicated in this and other districts throughout the country promises to be of great interest and value.

DISCUSSION.

President: Gentlemen, this has been a very interesting paper and is now open for discussion. Major Newcomer, we would like to hear from you.

Major Newcomer: I regret to state that I did not come prepared to discuss this paper. I did not know until today that it would be read this evening, nor until this moment that there would be an opportunity to discuss it now. There are, of course, a number of problems touched upon that are of great interest to me, but I would not like to attempt an expression of my views for record in your proceedings without first considering the matter carefully with that object in view. Pos-

sibly, with your kind permission, I may be able to present something later in writing for your consideration, though the investigation referred to by Colonel Roberts as now in progress in my office, together with other pressing duties, may not allow me to take this matter up in the near future.

Mr. Hirsch: I notice some tie rods on this drawing. Is much of the concrete of the reinforced type or is it monolithic?

Col. Roberts: They are all simple monoliths in the lock walls. In the case of the dam, it was cut away so much for conduits, we thought it advisable to use some steel rods.

Mr. Lyons: Do I understand that the high water in March, 1907, which is the record, was due to the Allegheny and Monongahela being at flood height at the same time, and is such a thing likely to occur again?

Col. Roberts: In reply to the first question, I would say, "yes." In answer to the second, I would say, "that is quite possible." The flood was local and was not high at the headwaters of either the Allegheny or Monongahela. The reports show that the rain fall was much less up there, and the snow at the head of the Allegheny did not all melt; most of the precipitation was within 75 miles of Pittsburgh. A few miles both above and below the city, the flood was less in height than some previous floods. The Youghiogheny was the chief contributor to the flood from the Monongahela. The breaking of ice gorges in the Allegheny added possibly a foot or two to the height of the flood.

In connection with the height of floods at Pittsburgh, there is good reason to think they are somewhat affected by the shape of Brunot's island, two miles below the city. The left chute of the island continues the course of the river and probably carries half the discharge volume. At the foot of the island, however, it makes an abrupt turn, joining the other channel at a right angle. Levels to flood marks show that the water was piled, or gorged, so to speak, below the mouth of Chartier's creek in the hard bend, standing at 2 ft. higher elevation than the water at the foot of the island. Here, therefore, was a slope of about 1000 ft. length dropping about 2

ft., and this where the water was fully 50 ft. deep. The re-entry of this water at a very high velocity, perhaps nearly ten miles per hour, by developing under water cross-currents, amounts to a positive obstruction to the free flow of the river. The flood level at Pittsburgh might be considerably reduced by removing one-half of the island and using the material for filling up the left chute.

Mr. Lyons: Hasn't there been an unusual volume of water passing down the Ohio almost all this season? I see the river nearly every day and I have noticed that for three or four days at a time, it may not vary more than a foot.

Col. Roberts: Yes. The flood last March was the greatest flood of 35 years' record in the discharge per unit of time, but was greatly exceeded in total volume by the great flood of 1884. We will show all these details by days, months, and years, on cross-section paper when the work, now being done under Major Newcomer's direction, is completed.

Mr. Hirsch: Have records been made of the amount of encroachment on the river banks in the last 25 or 30 years? The Lake Erie railroad was originally a high trestle built along the water's edge, but it is far from the shore line today.

Col. Roberts: There is probably 300 ft. encroachment on the Monongahela river right at the Smithfield street bridge. Years ago when I was a junior assistant in the Government service our little survey steamer would come up the river and tie at the end of the Smithfield street bridge very near Carson street; three spans of the old bridge were filled up. At the Tenth street bridge there are two spans filled up on the south end, and one on the north end. At this bridge, the river is narrower than at any other point below McKeesport. It is pretty hard to determine what effects these shore encroachments really have on floods. On the profile of the flood of March, 1907, which was carried from a number of miles down the Ohio, and up the Monongahela to McKeesport, the contraction at the Tenth street bridge, where the river is 730 ft. wide as compared with about 900 ft. above and below that point, indicates a local swell of only about 0.3 ft.

Assuming that about one-sixth of the old original channel of the river is obstructed by the encroachments at this bridge and that the velocity during the March flood was five miles per hour, according to the old Nicholson rule, to be found in Trautwine, the increase of head due to the obstruction should be about 0.4 ft. However, with no back-water effect from the Allegheny, during a great Monongahela flood such as that of 1888, (the greatest known), the velocity at Tenth street is much more than five miles per hour, and hence there would have resulted a greater proportionate head to overcome the effect of contraction. But, as the 1888 flood, while 42 ft. at Lock No. 4, made only 23 ft. at Pittsburgh, an extra rise of a foot or so above the 23 ft. stage at Tenth street, would not have been a serious matter.

Caution, therefore, must be exercised in estimating the effect of shore encroachments in increasing flood heights.

Mr. Hopkins: I would like to ask if the left-hand channel at Brunot's island carries the bulk of the water during flood stage? I was down there during the flood and I thought that such was the case; at any rate most of the ice appeared to be going that way. Referring to the fact that the Government has been cleaning out the bar at the mouth of Turtle creek, I would like to ask if the Government has any authority over tributary streams, not navigable waters, for any distance above their mouths?

Col. Roberts: We have never measured the river at that point during flood stage. Under Act of Congress, the authority of the Government covers any tributary stream. Owing to the new dam at No. 2, they have had so much high water at the mouth of Turtle creek that it does not appear as if much deposit was forming there; but this spring one of the boats coming along touched bottom where there ought to be 18 ft. of water.

Mr. Hopkins: I think most of the mines that were formerly worked in the Turtle creek valley are now abandoned, excepting for a considerable distance above the mouth of the creek, and that the manufactories do not now contribute to

any great extent to the filling-in of the channel. Most of the manufacturing establishments contiguous to the stream have built retaining walls to protect the banks from caving and to aid in straightening the channel. There has been, however, extensive railroad construction which has contributed a great amount of material from the cuts and embankments, and also a large amount of street and road grading which also adds to the debris in the creek. The towns in the Turtle creek valley would certainly be glad to see some steps taken to stop the filling-in of the channel.

Col. Roberts: In the interests of navigation it is very important that it be stopped. It is a great annoyance and expense to the Government.

H. J. Lewis: I wish to express my appreciation of the paper as a whole, for it is a contribution to engineering literature on a subject upon which information is very scarce. There is a great deal of literature on storage dams, but very little on the subject of an over-flow dam on a navigable river.

There is a very interesting point in connection with this. There seems to be a tendency for a pool to form below the dam. Will Col. Roberts please explain why?

Col. Roberts: When Dam No. 2 was designed we thought we would not have quite as much scour below on account of the apron throwing the water off horizontally, but there really does not seem to be any difference. New Dam No. 3 is almost a duplicate of the one at No. 2, and yet the scour below it has already exceeded 30 ft. depth in places, but it has been made secure by depositing several thousand yards of old lock masonry below the apron.

Mr. Lewis: Don't you think there is a decided return eddy in the bottom?

Col. Roberts: Certainly. In some dams drift timbers will come back and remain for days, until they are worn out coming back and hitting the dam. At the Holyoke dam in the Connecticut river, where there is rather a compact rock bottom, the logs from the pineries caught in the eddies below the dam, in the course of a number of years, quarried out the

rock bed to a depth of 25 ft., and even partially undermined the structure of the dam itself. Eventually a new dam had to be built.

Drawing marked, fig. 2, shows the scouring effect of the current below the dam, the river bed being cut to a depth of probably 30 ft. at a distance of some 150 ft. from the upper face of the dam. At the same time, boulders, gravel and sand are piled up at the point where the energy of the current has expended itself, forming a reef which, in turn, produces an eddy or return under-current.

Mr. Lyons: In some of the dams, built recently, has not that portion of the crib work, where the water falls, been constructed at an angle, a foot or so higher at the outer edge?

J. W. Arras: There is only one instance that I think of now where top of crib is inclined upward, and that is not in connection with a fixed dam, but is the apron, or protection crib at Herr's island dam which is a movable one. There the apron crib is inclined upward 2 ft. in 20 ft., rising from floor of movable dam to the level of its sill. There was a double purpose in that construction: First, to provide protection to the wickets from below, so that loaded ascending craft, drawing more water than is on the sill, could not strike and injure them. Second: To get what possible advantage there might be in a crib construction of that kind to carry the scour farther down stream. In that particular case we attained both the objects for which the crib was built. As Col. Roberts has said, however, the principle has not applied so well to fixed dams, perhaps, as he indicated, for the reason that concrete dams are not nearly as wide as the crib dams formerly constructed, and, at the higher stages of water, it is probable that the force of the water carries the scouring effect, or eddy, vertical or otherwise, entirely over the narrow apron until it strikes the more easily eroded material below. There was, however, an apron on the original back channel fixed dam at Davis island, built to about the elevation of a 12 ft. stage in the Ohio, and, at the higher stages of water, as you will see, the movable dam across the main channel being down, did not

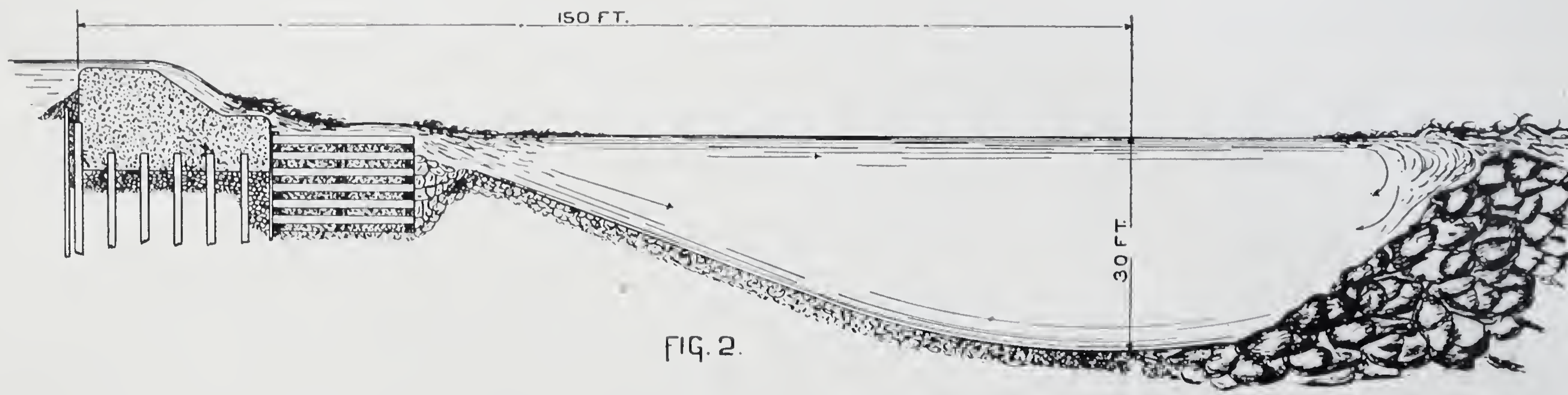


FIG. 2.

produce as great a head as would a similar dam crossing an entire stream. This apron was horizontal for perhaps ten or twelve feet and then inclined upwards 18 in., I should say, in about four feet. It had about the same effect on scour a hundred feet or more beyond the down-stream edge of the apron at its maximum depth and produced but little scour at the edge of the crib.

The horizontal crib, however, built in connection with the fixed dam at Springdale, which is a wooden crib 50 ft. in width and provided with a horizontal apron similar to the construction on the Monongahela river, resulted in the maximum scour at about 150 ft. beyond the dam, with little disturbance at edge of crib and showed that a horizontal crib below dam has a beneficial effect.

Col. Roberts: I will ask Mr. H. W. Brecht, who has been connected with the work, to answer a question, which one of the members has asked, in regard to the air pressure required for operating the "turtles."

Mr. H. W. Brecht, (Non-member): The machine was designed to take care of a 2 in. head of water; i. e., the water on one side of the gate being up to the top, and on the other side 2 in. below the top. A 1 in. head creates a pressure of 5000 lb., which, multiplied by 16 ft. (half the length of the gate) equals 80 000 lb. at the fulcrum; this divided by 4 ft., the length of the lever of the machine, gives a pressure of 20 000 lb. at the end of this lever. The pressure at the mean effective radius of the lever, for a 1-in. head, is 32 542 lb. The air pressure is 100 lb. per sq. in.

Machinery around the rivers and on lock walls is subject to floods. We have some small engines for operating the lock gates, which are placed down in recesses in the lock walls to protect them against injury from heavy drift which is washed over the lock walls during floods. There is a deposit of sand and grit after a flood which finds its way into all the working parts of an engine and sooner or later ruins it. Therefore, the simpler a machine is designed for a lock, the better. This so-called "turtle" is very simple in construction and needs no

further attention than oiling. It is very strongly built to stand the shocks to which it is subjected, and there are no exposed working parts to be affected by the sand and grit.

It may not seem practicable to take hold of the gate at the heel, but by so doing we overcome these other important things.

Col. Roberts: Most of the locks on the Monongahela are opened with a spar and pulled back with chains. I was a little afraid of the "turtles," before they were tried, because of my experience with wooden gates. When the lower arms get soft in the water the tendency is for them to sag at the toe posts; they gradually drop 4 in. in extreme cases. This means that the gate will bind very hard at the top when closed with the pressure against them. If the two leaves do not come together exactly right they take a "set" that is very hard to release. I have known them repeatedly to break ¾ in. chains in attempts to pull back wooden lock gates which were not properly closed. So, I was afraid we would have trouble with any plan proposing to catch the gate at the heel post. But steel gates haven't the habit of sagging down at the toe posts, and, so far, the "turtle" plan has been very successful.

(The paper was illustrated by a large number of lantern slides showing views of the improvements while under construction, and details of design of the locks and dams.—Ed.)

Before the Mechanical Section, April 7th, 1908.

Chairman G. E. Flanagan
Presiding.

CHAINS AND CHAIN MAKING.

By James H. Baker,*
Member.

This paper is not intended to instruct the chain manufacturer, but will, the writer hopes, be of interest to the Society in general, and shall be gratified if the matter presented is found to contain any suggestions of value to our manufacturers. I have asked all manufacturers who, I supposed, were making something new, to send me samples and information. Some have done so and others have courteously replied that they had nothing new. In presenting these samples and discussing the information obtained, it would be very wrong to misrepresent any manufacturer, and equally wrong to give a favorable opinion of an article or process when they do not seem to warrant it.

Just when chains were first made must be left in mystery, because the word has meant almost any kind of connection, as for instance, a chain of mountains. It seems that the first chains used, and that was thousands of years ago, were rings of metal fastened to cloth, thus making chain armor. Later, rings were joined together by other metal rings, and this was the first metal chain. Up to about 125 years ago there seems to be more mention of chains as ornaments than for any other purpose, although there had been an occasional patent issued as far back as 275 years.

The first patent I can find an account of was issued in England in 1634 and was described as follows:

"A WAY FOR THE MEARING OF SHIPPS WITH IRON CHAYNES BY FINDING OUT THE TRUE HEATING PPAEING AND TEMPING OF IYRON FOR THAT

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* Forging Engineer.

PPOSE, AND THAT HE HATH NOWE ATTAYNED TO THE TRUE VSE OF THE SAID CHAYNES, AND THAT THE SAME WILBE FOR THE GREAT SAVEING OF CORDAGE AND SAFETY OF SHIPPS, AND WILL REDOUND TO THE GOOD OF OUR COMON WEALTH."

More than 50 years elapsed, and in 1690 a British admiral recommended that chain moorings be introduced into the English service; but not until 100 years ago were chains used as ships' cables. (By the way, the original meaning of the word "cable," was "capable"). For nearly a hundred years more we hear of no progress. It is interesting to note that almost every conceivable form of chain was brought forward during about one generation, from 1790 to 1820. True, there have been many new machines invented for making the different forms of chain, but even now nearly all the chain made in this country, of the welded type, is made either by hand or under very simple power hammers. There has been quite a development in wound wire or weldless chains, and electric welding has made progress within the last 25 years; but both these methods have, so far, only been successful in light chains. Wire wound chains hardly run over ¼ in., and electrically-welded, not over ½ in.

In 1783 a patent was issued in England for making chain by casting one link in another and annealing the chain when done. Later, this method was tried under modern conditions in France, but has not been a success. Another patent, in 1791, covered a combination of metal and leather designed to prevent noise and give elasticity, prompted probably by the fact that hempen cables were noiseless and would stretch and recover a great deal. Iron chains were much objected to because they would not stretch. In 1808 the first chain was put on a vessel as a cable, and then patents in England came thick and fast. The one which probably had the most to do with furthering the use of chain cables was granted in 1808 to Samuel Brown, covering swivels and shackles. The shackles, fig. 1, met the greatest objection directed against iron cables,

which was that they could not be parted quickly, while a hempen cable could easily be cut. The pin A, fig. 1, being tapered, was easily removed and then the bolt B could be driven out. Another patent was for a method of coating these pins with a soft, non-corrosive material. There has hardly been any change in the form of shackle since it was first patented. In this connection it should be noted that all shackles, rings, hooks, end-links, etc., should be heavier than the body of the chain; often much heavier. The shackle shown is a joining shackle. End, or anchor shackles were and are larger.

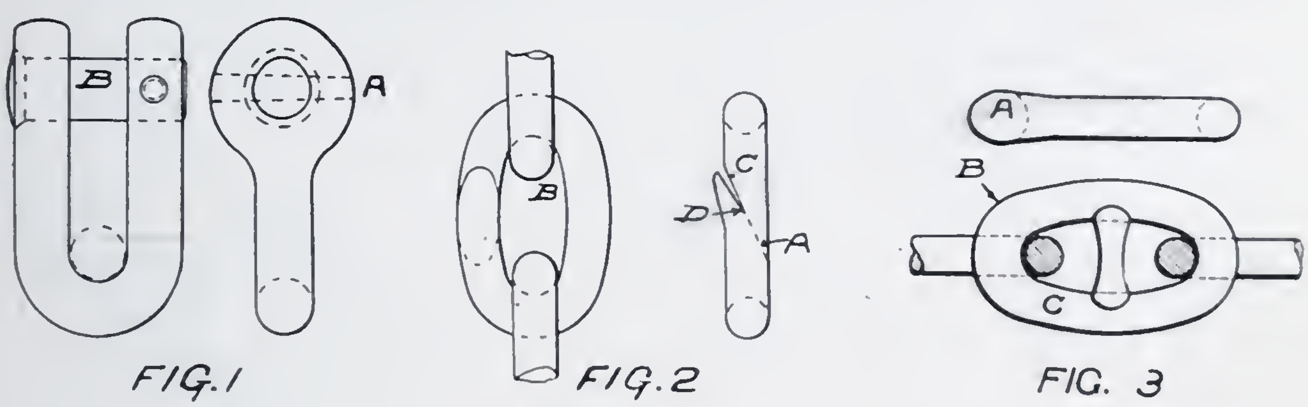


FIG. 1 FIG. 2 FIG. 3

In order to meet the stretch of hempen cables, twisted links with studs in them were patented; it was claimed that a cable of these would stretch and recover 8 or 10 ft., but they never came into general use.

*Side welding was practised more or less, but not until about 1840 was it made a matter of prominence; more so as sizes increased. Side welding has fallen into disrepute with the U. S. Government, which, I think, is clearly due to the method by which side welds are made. Fig. 2 shows a link, of which one-half of the lap at A has been welded; the link B is then shifted to the other end and the remaining part of the lap C welded. But in many cases slag imprisoned at D prevents a good weld being made, and the larger the diameter the more difficult it is to expel this slag by hand working. Further, large links are hard to heat properly with the cold link B in such close proximity. Stud chain in the largest sizes, if made as it should be, by proper machinery, would undoubtedly be the

* From "Chain Cables and Chains," by Thomas W. Trail; Crosby, Lockwood & Company, London.

best as well as the lowest priced, and that such machinery can be devised I have no doubt. The only end-welded chain comparable to a good side-welded article is hand-welded, and that is expensive.

Stud chain as we know it, fig. 3, was patented in 1813, and seems to be the last English patent of much consequence, though many efforts were made in the following ten years to improve chain. Studs were welded in the links, but these soon passed away, and have mostly been of cast iron. Our Government now uses drop forged studs and demands that the grooves for the links be milled. During all this time unstudded close-link chain, kept pace in the manufacture and in the improvement of the iron for making it. But little has been said about close-link chain, as the interest largely centered in ships' cables. Nearly all improvements as to forms of welded chain were made in England, but we have made great progress in this country in the matter of increasing production, and stand abreast with any in the matter of fine material for chains.

At A, fig. 3, is shown a "crown" at the weld, which all fine end-welded links have, and this swell is often also sidewise; but, even with the "crown," the links will be weak at the point where the ends of the laps come, indicated by the arrow at B. The very best of end-welded links have the ends of the laps carried back on the sides as far as possible, say to C.

In 1811 an English patent was granted for winding rods into a spiral from which the links were cut; fig. 4 shows a device which was operated by hand, working the rod hot as it

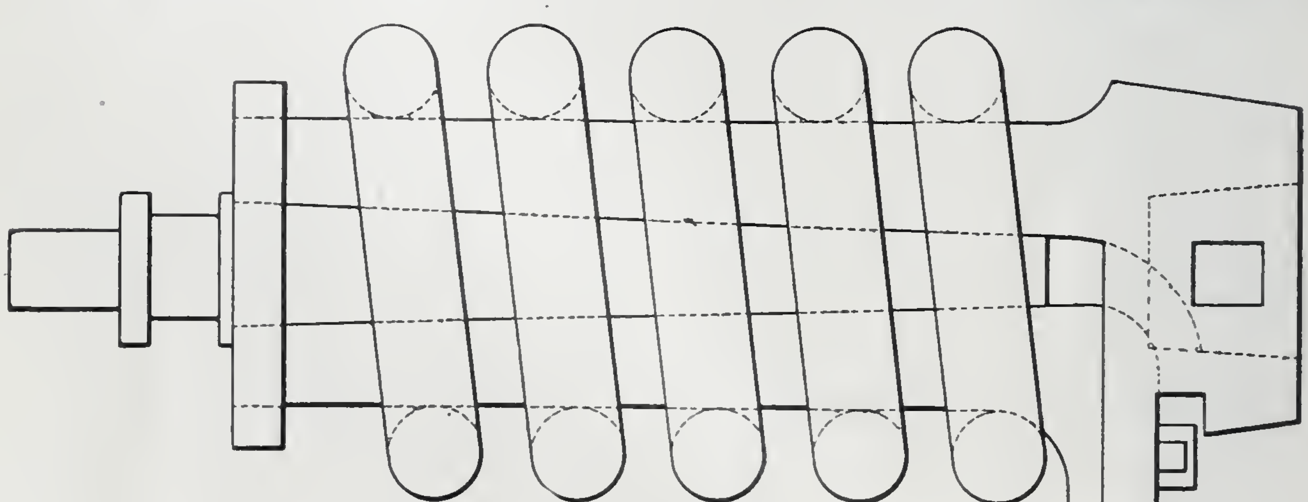


FIG. 4

came from the rolls. Fig. 5 shows a blank of half-round section which was bent twice around and welded together. Fig. 6 shows a blank made of square bar bent three times around and welded. Fig. 7 shows a Belgian method. Of these, I consider the plan shown in fig. 6 to be the best, but this compound winding and welding at the same heat has the objection of necessitating the links to be of too great length for many purposes.

FIG. 5

FIG. 6

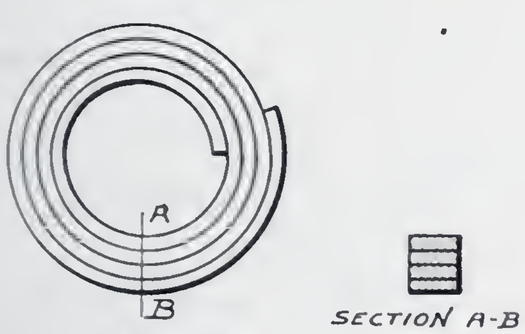


FIG. 7

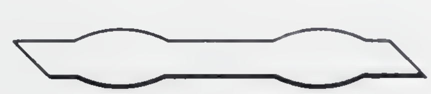


FIG. 8

FIG. 9

FIG. 10

An English patent, granted in 1812, covered a form of link blanks, fig. 8, forged with heavy parts to form the ends of the links, the purpose of which is obvious. Fig. 9 and 10 show an effort to form the studs integral with the links. Fig. 11 and 12 show links welded and looped and this is probably one of the oldest forms of chain, although at first the links were not welded. Fig. 13 shows the method practiced about 80 years ago for rolling link stock so as to give extra strength at the welds. The material was rolled in the usual way to the size

of the large part, was then passed through an extra set of rolls to reduce the intermediate parts, and was cut at an angle while hot. Fig. 14 shows a plan for making links from a solid bar, cutting at an angle; after cutting out central portions EE, the parts AA and BB are bent and welded together. This plan has been elaborately tried in other forms, such as star section, but I do not believe the idea can be made practical. It will be noted that all of the above efforts, except the Belgian and the intermediate rolling process, were made within about 14 years from the introduction of the first iron cable in 1808.

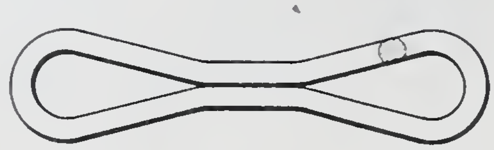


FIG. 11

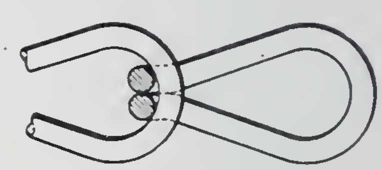


FIG. 12

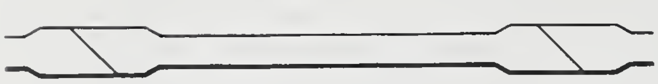


FIG. 13

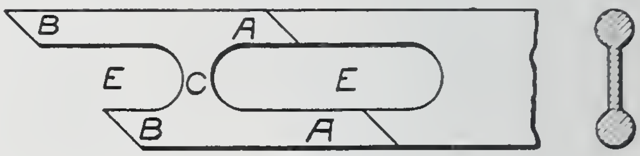


FIG. 14

Coming to this country, it seems a little strange that the largest chain of any length ever produced here was made about 130 years ago, when there was not a rolling mill or steam hammer in the country. There were 500 yards of this chain, the links being made of 3½ in. square with corners slightly rounded, and each link weighed about 275 lb. Through the courtesy of Mr. J. G. Schmit, President of the Standard Chain Company, I am enabled to have a sample link of this chain before you. This chain cost the Colonies over $2000 per ton, and was made for the purpose of preventing British ships ascending the upper Hudson river, the chain being held at the desired height by logs bolted together. Notwithstanding all the English enterprise, it was nearly fifty years after the production of this large chain here before that country made a chain as large even as 1½ in., and it appears that this country has

not since made as large a chain as this first one. The contract for this chain was awarded in the evening and work was commenced on it the next morning at Sterling, about twenty miles back of West Point, N. Y. Seventeen forges were engaged in the work, ten for forging proper and seven for welding.

The history of chain making in this country is meagre indeed, so far as records go, and there was little chain made in factories until about the time of the Civil war. It seems there was a ships' cable chain works established about 1835 or 1840 in Boston, and in 1865 the Carr Chain Works was incorporated at Troy, N. Y., and became quite a factor, especially in fine chains; this company was, I believe, in some way connected with the Burden Iron Works. About the same time A. Hewitt & Co. established a works in Trenton, N. J., which also made much progress. One among the earliest manufacturers, was the Hayden Chain Works at Columbus, Ohio, which started by making harness and saddlery chains. They finally engaged in making high class crane chains, and was perhaps as great a factor as any in displacing English chain in this country. Even up to 20 years ago English chain still had a hold here, one brand, the "Lord Ward," being very popular for certain work.

I need not go into the enumeration of chain works at present in existence, but am glad to say that Pittsburgh today is the largest producer of chains in the country, and not only stands first in production, but it is at the head in fine chain material in both iron and steel.

Many curious and some very ingenious chain-making machines have been invented, and while many patents have been issued in this country for processes such as making it automatically from the straight rod, the great bulk of all chain is hand-welded; crane chains, and in fact all chains 1¼ in. and larger, if not strictly hand-welded, are nearly so. Most of the smaller chain of the usual quality is made by coiling the links, cutting them at an angle and welding in dies. Originally, the hammers carrying the dies were mostly operated by the workman's foot, but power is being applied to these operations to an ever-increasing extent, even down to quite light chains.

Men become very expert and a good man or boy can cut 250 light links per minute while they are wound at a very rapid rate, and in light chain, an expert can weld 500 links per hour.

The heating is usually done in flat-top furnaces, the links being suspended through holes in the top of the furnace and held by rods with hooks on their ends; usually, a boy places the links on the hooks and puts them into the furnace. When one considers that the chain maker has to lift this link from the furnace with one hand, catch it with tongs in the other, thread it into the chain, place it in the dies and turn it once or twice while welding, expert chain making becomes an interesting operation.

At this point the author exhibited a number of specimens of chain consisting of the following:

Swedish iron chain, 3/8 in. diameter; broke at 10 900 lb.

Steel chain, 3/8 in. diameter; broke at 11 800 lb.

Crane chain, 3/4 in. diameter; broke at 44 600 lb.

Dredge chain, specially hard fibrous iron; tensile strength 52 000 lb. per sq. in.

There were also exhibited specimens of roller, noiseless tooth, and electrically-welded chains; common 1/4 in. trace chain, electrically-welded and capable of withstanding strains varying from 1500 lb. to 2400 lb. and probably as much as 4000 lb.; weldless sash-weight chain; brazed surveyors' chains; double eye loop chain; steel chain having qualities similar to Swedish iron in extreme elongation. Also two 5/8 in. lap links, one, which had been tested withstood a strain of 21 000 lb., while proof chain of this size should stand about 23 000 lb.; these links are used as repair links for crane chains, give practically the full strength of the chain and do not interfere with their proper working.

Electric welding of chain was first tried about a quarter of a century ago, joining two half links, fig. 15, at A. Links as large as 3 in. diameter have been made by this method which seems to have been abandoned for large chain. Later, this plan has been successfully used, but so far as I can learn, only on small sizes. Recently electrically-welded chain up to 1/2 in. has

been made commercially by automatically cutting the blanks from a bar so as to form a socket in one end and a corresponding taper on the other end of the link blank, fig. 16. The blank is then bent, joined on one side and the joints welded; this obviates the usual amount of upsetting. The lap, or area of contact, is much larger than in the squarely cut ends, and a nice-appearing and good weld is made.

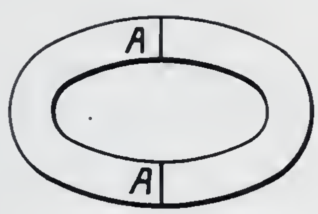


FIG. 15

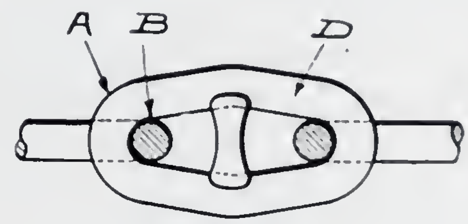


FIG. 17

FIG. 16

Weldless chains have superior strength in the small sizes, say below ¼ in., because the wire from which they are made, being cold-drawn, has a much greater strength than rod steel; and the smaller the chain the more difficult it is to make a weld which will be as strong as the rod from which the link is made.

All manufacturers give tables on chain, and Trail, already referred to, gives a most complete collection of tables. I have deduced some formulas I have found useful. From the nature of the case, figures as to the strength of chain can only be given approximately.

DIMENSIONS OF LINKS.

Stud chain: Maximum length inside, four diameters of the bar from which it is made; maximum width inside, 60 per cent of inside maximum length.

Standard close-link: Maximum length inside, three diameters of the bar from which it is made; maximum width inside, 70 per cent of the maximum length inside.

Coil chain: This generally runs about like close-link but, if anything, somewhat longer in the links.

Crane chain: Length inside $2\frac{5}{8}$ times the diameter of the bar from which it is made, but it varies somewhat. As a rule, the shorter the link, the better. Note—Allowable variations under maximum dimensions may not be over four per cent, and should not be more than two per cent.

WEIGHTS.

Stud chain: $3\frac{3}{4}$ times the weight of the bar from which it is made. This includes the stud, it being equalized by the extra length of link.

Standard close-link: $3\frac{3}{4}$ times the weight of the bar from which it is made.

Coil chain: $3\frac{5}{8}$ times the weight of the bar from which it is made.

Crane chain: 4 times the weight of the bar from which it is made. This extra weight is due to the links being somewhat shorter, and to the "crowns" on the welded ends being heavier than on common links.

BREAKING STRENGTH FOR WELL MADE CHAIN.

Stud chain: 165 per cent of the strength of the bar from which it is made.

Standard close-link: 138 per cent of the strength of the bar from which it is made.

Coil chain: 120 per cent of the strength of the bar from which it is made.

B. B. crane chain: 145 per cent of the strength of the bar from which it is made.

It will be noted that the weight and strength run a little higher on the light sizes up to about 1 in. as the bars from which these are made are $\frac{1}{32}$ in. larger in diameter than the nominal size of the chain. When in light sizes the chain is made of exact size bars the chain size is given as "neat." Ordi-

nary, or die chain, from ¼ in. down, becomes less and less in strength compared with the bar as the sizes become smaller; hence the greater strength of weldless chains in the very small sizes.

Fig. 17 shows how the sides of the links straighten at D and bend at A when the chain has been loaded sufficient to distort the links, and explains why links will not stand double the load of the bar. While the metal is stretching generally, the stretch is very much greater in the outer line at the quarter, and added to this is the fact that the ends of the laps come about at this point.

The chains of commerce have as many names as the uses to which they are put; but some terms need a word in explanation. "Proof chain" is a term applied to chain that has been pulled in a testing machine up to a certain strain. This is usually somewhat below one-half of the load it should take to break the chain. "B. chain" is an abbreviation of "best;" competition resulted in "best-best" and later "B.B.B." (3-B), so that hardly anyone now speaks of 1-B chain. Well made chain of Swedish iron, when pulled to the breaking point, is stiff enough for a walking stick, owing to the links closing in on each other sidewise. "Dredge chain" is the same as "3-B," but should have special attention paid to the hardness of its stock to stand wear in sand and dirt. Nearly all of our common chain is now made of steel, and a good deal of it, above the common grade, is also made of this material and is giving satisfactory service. For particular purposes, especially where great safety and resistance to wear are required, special iron is keeping first place.

WEAR.

The greater the number of links in a given length, the longer the chain will wear; the greater the angle at which the links play in each other, the faster the wear, and sometimes there will be more than double the wear in one part than in another. The old style tongue chain on wagons wore much faster next to the tongue than at the horse's collar; breast

chains wore faster in the centre than at the ends next to the horse's shoulder, and it used to be the custom to make these chains with heavier parts accordingly.

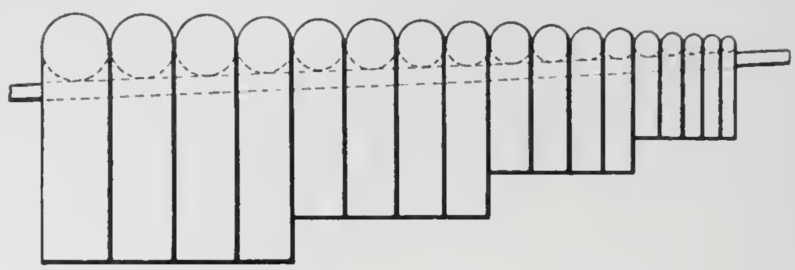


FIG. 18

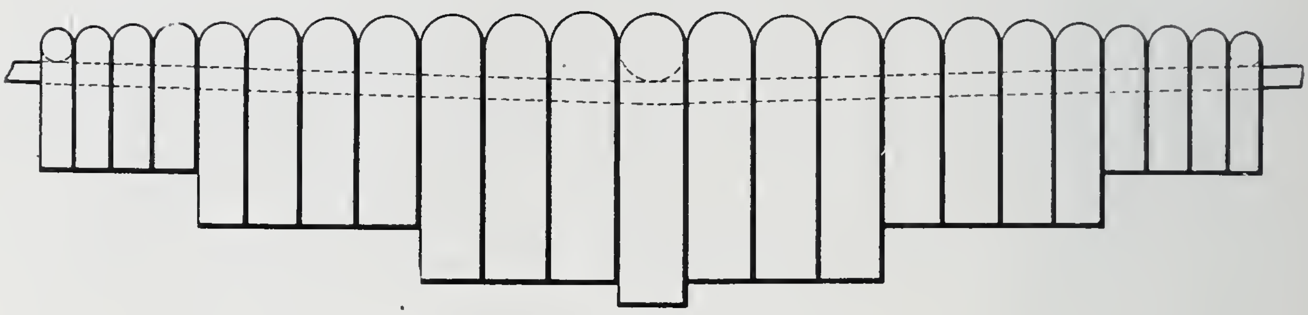


FIG. 19

It may be of interest to know how such chains were made, though I believe all such methods have been abandoned. The links were forged in several sizes and lengths, and pains were taken to forge the sizes somewhat unevenly. The links were then strung on a rod, fig. 18 for tongue chains, and fig. 19 for breast chains. After being placed on the rod according to length, each length was assorted by the eye as to diameter, thus grading them fairly well. Commencing with the first, in fig. 18, the heaviest one was welded up full length, the next cut off a trifle at the ends, the next still shorter and so on. The same method was pursued with the links in fig. 19.

Chains used in critical places should be annealed at times. The principal need for this arises from strains sufficient to bend the links, this bending, being really "cold work," hardens the material. If one can be certain that a chain has had no strain over about ¼ of its proof strength, or ⅛ of its breaking load, there is little occasion for annealing. But if a chain has been strained well up to its ultimate strength, it should be annealed,

even if that be every day; but there is no sense in using a chain up to this limit except in dire need.

RELIABILITY.

Much depends on the honesty of the manufacturer and the chain maker. Rugged honesty in the manufacturer has an influence on his workmen, because he will endeavor to employ only honest men—men who appreciate that the chains they make would be dangerous to use if not made with proper care. This may seem to be a platitude, but preference should be given at all times to men who have the best character for honesty; a good chain maker knows when he is making a doubtful weld. While all chain for important work is generally proved, proving does not tell all the story. However, users should understand that they should not expect common chain, which has a wide and useful field of its own, to equal the higher class of product required for certain purposes.

DISCUSSION.

Mr. L. J. Wilson: I would like to ask the speaker if there is any chain made in this country by machinery; running a bar in and bringing it out a chain, without welding; what might be called, "rolled forging."

Mr. Baker: I do not know of any such chain made in this country. There is a rolled chain, but the links are bent and welded as the material passes through the machine.

Mr. H. H. Anderson: The process referred to by Mr. Wilson was tried by the Carnegie Steel Company about the year 1890 or 1891. As far as I remember, they had a cruciform section through which they drilled holes at right angles with one another. After forming the outside of the links the holes were spread and the links parted in such a manner as to form a chain. They did not seem to have much success, however, as they never went far enough to put it on the market.

Mr. Baker had a very ingenious machine whereby the links and the lap for welding were formed in one operation.

The material was bent around a former for one end of the link and, at the same time, two arms forced the metal around to form the opposite end of the link. They were then scarfed and welded under small Bradley hammers.

Mr. Albree: A year or more ago there was a good deal in the technical papers about a chain made, I think, in Belgium, where they rolled a star-shaped section and alternately cut out, what you might call the "web," for a distance first on one side and then on the other; it was then put in dies and hammered until it made almost a link each way and was finally separated, a chain without any weld whatever. It was very ingenious and they claimed it would work very well. Perhaps that is what Mr. Wilson referred to.

Mr. Moore: Mr. Baker referred to Mr. Abram Hewitt as an early chain maker. His oldest son, Cooper Hewitt, was said to have spent a large amount of money trying to build rolls so constructed that they would roll a chain out of a solid bar. That was 12 or 14 years ago and it was understood at the time to be a failure in every sense of the word.

Mr. Winter: The matter Mr. Albree referred to is probably a modification of a process that was patented in this country and in many foreign countries, about ten years ago, by a German engineed named Klatte. He takes a cruciform bar and runs it through rolls which cut it out until links are formed and separated. I have been told that the process was worked in England with a fair degree of success, but I never knew that it was attempted in this country. It was an interesting thing, but any one studying the patent drawings would come to the conclusion that there would be considerable strain on the material, rupturing it in the process of cutting through the webs of the cruciform bar and separating the links. The commercial obstacle was probably due to the cost and the difficulty of getting satisfactory and uniform results.

Mr. Baker has referred to electric welding, of which a recent process was called to his attention where the joint was scarfed and a protuberance formed on one of the surfaces in order to get a proper weld. The process is really quite old

and I think the foundation patents of Mr. Edison expired a number of years ago. For a great many uses electric welding has not been a commercial success, but some of the recent improvements have made the process satisfactory for various purposes. It was my privilege, something over a year ago, to look into a process for welding flat plates together. It had been attempted to weld flat faces, but for some reason a good weld could not be made. Either the plates were merely sweated together, or else the long continued applications of the current would crystallize the material, making the weld imperfect. Parties in Philadelphia and others in New York, working in conjunction with the Thompson-Houston Co., of Lynn., Mass., developed a process for welding flat pieces together, which they claim is entirely satisfactory. They found that it was necessary to form protuberances or projections on one of the surfaces so that the two plates were not in contact for the full width but only at successive points. It was spoken of as the "point contact weld"; the plates were not welded entirely across but were firmly welded together at these points of contact. I understand the American Pulley Company uses the process for welding together the two halves of sheet metal sheaves. The welding of a bar against the face of a flat plate was tried about a year and a half ago, by forming a protuberance on the plate, or by turning down the end of the bar leaving a projection at its center. This worked satisfactorily but the projection had to be of a particular conformation and cross-section.

The theory is, that by having a point contact, the current is concentrated at the time it begins to flow, gives a very high heat at the point of contact and practically melts the metal; as the pressure brings the two pieces together, the central zone, which is practically melted, offers greater resistance to the current and it follows a circle around that central zone, gradually increasing the zone of weld. Undoubtedly that was an application of the same principle as the welding of the two flat surfaces of the chain link.

Mr. Baker showed a sample of an electrically-welded trace

chain, and if you examine it you will find that the point where the weld is made is slightly greater in diameter than the bar from which it was made; this is one of the difficulties of electric welding. The best welds can be made with a butt weld, but it forms that enlargement of the bar, a thing which has always occurred in electric welding and which they have tried to minimize as far as possible. One of the older attempts, and one which has been followed in other lines, is to taper the two ends of the bar, so that when the metal squeezes out it simply closes up the annular groove which would otherwise encircle the bar.

The Secretary here read the following contribution from Mr. F. Z. Schellenberg:

It has been said that the first highway suspension bridge was built in Pennsylvania, on the road from Uniontown to Greensburg, across Jacob's creek. It must have been at the place near Mt. Pleasant, in Westmoreland county, known as Iron Bridge station. It was said to have been a chain bridge, made of links forged in a blacksmith shop, and that the builder, James Finley, of Fayette county, erected some six such bridges of greater importance.

Trautwine states that Finley began this work in 1796, and that the links of his bridge were made of 1½ charcoal iron, and were seven to ten feet long. They were connected to each other by cross beams at about the middle of the span, and passed over wooden posts on the abutments to anchorages of heavy stones.

Mr. Hirsch: At the request of one of our members, who is not present tonight, I would like to ask if there is a formula for calculating the strains in a link of circular form; i. e., with a given load and given mean diameter of link, to determine the size of material sufficient to resist any tendency to distort the link from its true circular form.

Mr. Godfrey: A formula for a circular link is derived in "Green's Structural Mechanics." The formula is given in a simplified form in my book of "Tables." For a load P, on a ring of diameter D, the bending moment at the loads is .1592

P D, and at quadrant points it is .0908 P. D. At quadrant points the direct load acts with the bending moment.

Chairman: I think Mr. Nicholson could tell us a good deal about chain making, and the members would be pleased to hear from him.

Mr. Nicholson, (Non-member): A short description of the process of manufacturing hand-made chain may be interesting. The bar is cut into lengths, a number of which are put on a rack and heated before they are actually put into the fire. The chain maker takes a piece off the rack, heats it in a coke fire, between a cherry red and a white heat, and bends it into a U shape. It is placed in the fire again, scarfed on the ends, and, threaded on the hanging end of the chain, the two ends are lapped and laid over a "pick iron," corresponding to the horn of an anvil. The scarfing is done with a hand hammer having a blunt peen whose axis is parallel to the handle of the hammer. By this time the link is sometimes nearly welded, but it is always put back into the fire for a welding heat and finished up on a "dolly" into a completed link. Hand-made chain, ½ in. and larger, is made in this way, but in sizes smaller than ½ in. the chain maker heats the ends of the bar and cuts off the lengths himself.

The best chain makers are Englishmen. That seems strange in this country of progress, but the reason is this: There is a part of England, where they make chain exclusively, called the Black country, Staffordshire, and the chain makers make the chain at home. The merchant furnishes the iron and they have to return a certain percentage (about 92 per cent) of the iron in chain. Most of the houses have a forge in the back yard. There are four corners to the forge and four people can work at it. The father and mother make chain, and so do the children, as soon as they are old enough. They start in at ten years or younger, and some of them tell me of being tied to a chair, when they were too small to be allowed to run around, watching them make chain.

Mr. Danforth: I would like to ask if there is any difference in the strength of chain made of a certain size bar, and

coiled chain of the same size material. Is coiled chain much cheaper to make than the hand-made article?

Mr. Nicholson: If the chain is perfectly welded and made of the same material, I do not know why there should be any difference, although it seems to me that the winding of a bar of iron, cold, must decrease the strength of the iron. Most machine-made chain is of steel. For the very best grade of ½ in. machine-made chain, the chain maker is paid about $1.25 per 100 lb., but for the best grade of hand-made chain the chain maker gets $3.70.

Mr. Baker: It may be interesting to know that, with coke fuel, we experienced a loss of but ⅞ per cent in weight of the iron put into the furnace, while the loss in a natural gas furnace was 2¼ per cent.

Much might be said of the different forms of tools and of the different processes devised for making chain. I have not touched upon this, nor upon my reasons for believing that a chain made from a cruciform bar can never be a success as a commercial proposition. The art of chain making is a hundred years old, and I am rather skeptical about new things.

In making some heavy chain, one time, I found that we were running too close to the testing point, and, upon investigation, found that the chain makers were careless and were striking the links away back from the weld, bruising the material and impairing the strength of the link. By the exercise of proper care we made our 2 in. chain from 10 000 to 15 000 lb. stronger. The material should be carefully worked, and a link wound cold on a mandrel can never be as strong as one that is properly bent by hand. Bending the bar cold over a mandrel reduces the section, injures the iron and tends to produce incipient fractures at the corners.

Mr. Stucki: I would like to ask if it is not true that wrought iron chains do not need to be annealed as often as steel. I understand that steel chains have to be annealed more frequently as the carbon runs higher. Again, a chain that is used continuously undoubtedly has to be annealed oftener than one that is used only occasionally, and one that is used under high fibre stress should be similarly cared for. It is also pos-

sible that chains used in places having very high temperatures should be frequently annealed; and where human life is at hazard, every possible care should be used to insure their safety.

I would like to ask if there are any established rules or standards governing the periods of annealing.

Mr. Baker: When a chain is not used to any great degree of its strength, I think annealing a matter of inconsequence; but when used to a high stress it ought to be annealed every time it is so used. The metal that has been pulled until the links are distorted has been cold-worked, causing more or less brittleness and is in no condition to stand shock. Service which produces wear only, is not injurious to the material.

Annealing means a disintegration, or a lessening of the adhesion of the particles of the steel. A piece of annealed material will cut easier and will thread easier because the cohesion of the particles has been broken up to a certain extent. Here is a piece of chain bar that was heated, cut and bent double, and could not be broken. Here is a piece from the same bar, not six inches from it, that was given just a little different heat, nicked and it broke off like a piece of glass. That is the kind of annealing very often obtained. This so-called annealed piece of material would be easy to work in a lathe; but I doubt if it would be possible to cut a clean thread on this fibrous piece which could be bent double without breaking.

Mr. Diescher: If a chain is not strained to the limit of elasticity, why should it be annealed? If it is used beyond that limit and it begins to stretch, is it not stronger in that condition than it will be if annealed? It seems to me that chain is made weaker by annealing because it becomes softer.

Mr. Stucki: It is simply a question of crystallization. If chain is stretched, as Mr. Baker explained, it would certainly be stronger because you change your links from an approximately circular to an elongated form, but it is not safe when it has become crystallized. I know a shop where two sets of crane chains are kept; one is annealed every week and put into service Saturday night. In other places they anneal them every three months; in others once a year, and in many places

not until they break. A friend of mine who is an authority on such questions, considers a period of from nine to twelve months a fair and safe period, according to conditions.

Mr. Baker: I do not know of any such rule. Mr. Coffin, of the Cambria Steel Company, proved that you might take two pieces of steel, clean them perfectly, seal them in a platinum sheet so they cannot oxidize, and heating them to a fair red heat, they will be found, upon cooling, to be welded together. Any piece of iron or steel will break if bent often enough, but the less it is bent, the oftener it can be bent be fore breaking. What happens? The particles of metal have parted one by one and if the steel be made red hot and protected from the atmosphere, the surfaces of the particles of metal will again be joined together. I never heard that theory advanced, but I believe it explains the process of annealing.

Chairman: One feature of the subject has not been much touched upon, and that is the use of chains. We would like to hear something in respect to the merits of chains compared to wire rope.

Mr. Moore: I did not expect to say anything, for I am prejudiced against the use of chains. I want to qualify that statement by this, and I think Mr. Baker will bear me out in it. I believe chains should never be used except with a very liberal factor of safety, then there is never any necessity for annealing. I believe that is the solution of the whole matter; that the factor of safety should be so large that there would never be any necessity for annealing.

I would not think of using a piece of 5/8 in. chain where I would use a piece of 3/8 in. cast steel wire rope. This is based upon experience I have had in putting up cable-ways. I found that the best chain for this purpose was that which had been laid up and kept dry in some ship yard for probably fifty years, and by actual experience proved to be the best for cable anchorages. We sometimes put up cable-ways with 35 tons tension on the line, and when we come to put in a chain to carry that load, it means something. But I am prejudiced against chains unless there is a factor of safety of at least five.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXIV JUNE, 1908 No. 5

REGULAR MEETING,

May 19th, 1908.

Vice-President George T. Barnsley,

In the Chair.

THE OHIO RIVER.

A BRIEF DESCRIPTION OF ITS PRINCIPAL NAVIGATION IMPROVEMENTS, WITH MENTION OF SOME OF ITS CHARACTERISTICS.

By J. W. Arras,*

Member.

Similarity of slope, glacial deposits, volume of discharge, frequency of islands and other physical characteristics, significantly absent in the Monongahela, attest to the fact that the Ohio and Allegheny are one stream, of which the Monongahela is a tributary. Their names, in the various Indian dialects from which they were derived, mean "fair water," and indicate that they were recognized as one river by the Aborigines; but in some manner, the name of that part of the stream above the mouth of the Monongahela has undergone a change. Even as late as 1756, on a map of Pennsylvania published in London, the name "Ohio" is applied no less than three times to the stream above Fort Duquesne and now known as the Allegheny.

The length of the Ohio from its present recognized head at Pittsburgh to Cairo is 967 miles. With its tributaries it

*Assistant Engineer in Local Charge of Movable Dams in the Pittsburgh District.

drains an approximate area of 210 000 square miles, within which resides a population of about 12 000 000. Its average width along its upper half does not vary greatly, adhering closely to 1200 or 1300 ft. In the long pool above Louisville there is a marked increase in width, followed immediately below the falls by a material contraction; below this it gradually widens toward its mouth and attains its maximum width about twenty miles above Cairo, where it is considerably over a mile from bank to bank. In contemplation of the slack-water improvement of the river, this is a matter of great importance.

The course of this water-way is marked along its upper reach by coarse gravel and boulders; but going down stream, the former gradually becomes smaller, and the boulders less frequent until, at a point below the mouth of the Kanawha, a sand bed prevails, with the exception of some gravel-beds above the falls at Louisville. Only occasionally do rock ledges project from the bank slopes, or is rock bed visible or within easy reach, it generally being too low for foundation purposes for lock and dam construction as at present followed. Notable exceptions to this rule are to be found at the falls at Louisville, an irregular limestone formation occupying the entire river-bed for a distance of 2½ miles; another at Grand Chain, where a solid rock bed exists. At a few other places rock bottom appears, over the greater portion of the stream at least. In general, the river is a succession of natural pools alternating with gravel or sand-bars forming shallows, many of which have comparatively steep gradients.

At the headwaters the slope average for the first 29 miles, to Dam No. 6, is 1.433 ft. per mile. This high average exists largely because of the rapids about ten miles below Pittsburgh, where a fall of 9 ft. occurs within less than two miles. Below Dam No. 6, the average slope rapidly diminishes to approximately 0.77 ft. per mile, to Wheeling; thence to Louisville falls, 0.4 ft. per mile, and below the falls to the mouth of river, about 0.29 ft. per mile. The total fall is 424 ft., of which 26

ft. are at Louisville falls, leaving a general average slope of 0.413 ft. per mile for the remaining 964 miles of river.

No exact measurement of the extreme low-water discharge of the Ohio at its head seems to have been made. However, from various measurements of the three rivers at Pittsburgh at comparatively low stages, the approximate low-water discharge of the Ohio has been estimated to be 1600 cu. ft. per sec. A careful measurement of its maximum flood discharge, made on March 15, 1907, showed a run-off of 440 000 cu. ft. per sec.

TRIBUTARIES.

The Allegheny, Monongahela, Muskingum, Little Kanawha, Kanawha, Big Sandy, Kentucky, Green, Wabash, Cumberland and Tennessee rivers are the principal tributaries on which the Federal Government has undertaken works for the improvement of navigation. Sixty-eight dams have been constructed and are being maintained on these streams, affording a total of 958 miles of slack-water navigation, and several other locks and dams are under construction. There exists also, on the Tennessee river, a canal 18 miles long and having eleven locks. Of the dams, twelve are movable; eight on the Kanawha, two on the Big Sandy and one on the Allegheny, are composed of Chanoine wickets, and one on the Big Sandy is of Poiree needles; the remainder are fixed dams. Of these important tributaries, only the Allegheny, Muskingum and Wabash empty from the north.

NAVIGABILITY AND EARLY IMPROVEMENTS.

During much of the time the Ohio river, with but scattered improvements, is navigable for the open-river transportation of deep-draft vessels. Boats of 8½ ft. draft can run out of Pittsburgh on an average of 79 days per year, and can pass Louisville, 600 miles below, on an average of 97½ days per year. The stream also records, on its upper reach, an annual average of 85 days on which the stage is 3 ft. or less,

when only the smallest steam towing craft can navigate out of Pittsburgh without the aid of slack-water.

Congress having authorized a partial survey of the river in 1820, which was made the next year, followed this in 1824 with the first appropriation for the purpose of its improvement. The operations at that time were confined to the removal of snags and the betterment of certain sand-bars. In 1825 the State of Kentucky granted, to a stock company, a charter for the construction of the Louisville and Portland canal which was opened for traffic in 1830. The first work of a permanent nature undertaken by the Federal Government was the construction of dikes and wing dams on the lower river in 1831 and 1832, and the first work of this character above Louisville falls, was done in 1836 at Brown's island, 60 miles below Pittsburgh. These structures were built almost exclusively of large rough stone deposited in the stream on the lines of projected works, with little effort at systematic arrangement. Such construction work, for closing duplicate chutes or concentrating the flow of water on wide-spreading shallows, was continued from 1826 to 1844, when appropriations practically ceased until 1866. Upon their resumption, in the latter year, the works of channel contraction were taken up where suspended 22 years before and, together with snag and wreck removal and channel dredging, have continued all along the stream up to the present time. In 1876 the rough stone dams and dikes gave way to more substantial timber structures, ballasted with stone or furnace slag and roughly paved on their upper surfaces with stone.

Through these operations navigation has been greatly benefited, admittedly at considerable cost, and in view of the contemplated canalization of the Ohio, it will doubtless occur to some that much of the investment will, in a measure, have been wasted. Such, however, is not the case since considerable of the general and especially the heavy descending traffic will probably always be conducted in open-river with the mov-

able dams down, when the need for facilities for such navigation will be quite as great as ever.

IMPROVEMENT BY LOCKS AND DAMS.

Although the method of open-river improvements, briefly alluded to above, has added materially to the safety of navigation and appreciably lengthened the periods of navigable stages, yet the purpose of the project to maintain even a 3 ft. minimum channel depth has not yet been realized; nor is ft. minimum channel depth has not yet been realized; nor is it believed that it can be done within economical limits of cost for improvements and navigation operations, especially on the upper portion of the stream where the slope is steep and low-water discharge small for months at a time. It was early recognized that the most practical, economical and reliable plan for the radical improvement of the river was by means of locks and dams. This conclusion, as the records show, seems first to have been reached in 1870 by the eminent civil engineer, Mr. W. Milnor Roberts. Four years later, Major Wm. E. Merrill, Corps of Engineers, and then in charge of the Ohio river improvement, recommended the construction of 13 locks and movable dams with Chanoine wickets, between Pittsburgh and Wheeling. The recommendation was subsequently adopted as the most rational plan for maintaining a 6 ft. navigable depth in low-water seasons. Dams of this type are readily removable, making an open-river passage for large coal fleets during natural boating stages. In 1875, in pursuance of this recommendation, Congress appropriated $100 000, (quoting the exact wording of the act), "to be used for and applied towards the construction of a movable dam, or a dam with adjustable gates, for the purpose of testing substantially the best method of improving permanently the navigation of the Ohio river and its tribitaries." This dam, constructed at Davis island, was opened to traffic on October 7, 1885, and was the first movable dam established on a large ice and drift-bearing stream.

Major Merrill retained charge of this most important improvement during its entire construction, and devoted much of his personal attention to the numerous details of its various features. In adapting the Chanoine type of dam to the peculiar conditions pertaining to the upper Ohio and its navigation, he introduced several radical changes from well established rules, such as: The elimination of a trestle service-bridge for maneuvering the navigable-pass wickets, and the adoption of a maneuvering boat in its stead, operating from above the

View of rolling gate at Lock No. 6, on the Ohio river, showing the chain and drum for operating the gate.

dam; the introduction of an automatic weir for pool regulation and ice and drift disposal; abandonment of miter lock gates and the erection of rolling gates instead. In addition to these, many less important features were of new design. How well he accomplished the designing, selection and adaptation of the various devices combining to make up the aggregate of the vast works located at Davis island, is evident from the fact that few material changes have resulted after 23 years'

experience in its operation and in the construction and operation of others. The dimensions of Ohio river locks, arrangement of sills, type of gates and devices for their operation, sizes, number and, to a considerable extent, the arrangement of lock valves, and many other important features of the more recent structures stand today practically as they were originally built at Davis island. It seems strange that the engineer who so admirably conceived and executed this work and who, in 1875, expressed himself favorable to the extension of this movable dam system along the entire river, should, after only a few years' experience with the difficulties of its maintenance and operation, become so discouraged with it as to almost reject a proposition to erect a second one.

MOVABLE DAMS.

Movable dams have been divided into two general classes: Those operated by forces applied extraneously, and those maneuvered through the direct application of water or air as a lifting force, the latter being frequently called automatic dams. Of the two types comprising the Ohio river structures, the Chanoine dam belongs to the former class and the bear-trap to the latter. With the exception of the various designs of bear-trap dams, movable dams generally are the production of French engineers. The Chanoine wicket, the natural evolution of the old shutter valve or gate, combining therewith the principle of the balanced valve, was invented in 1852. It consists of a shutter hinged near its middle, together with its prop, to an iron frame support called the "horse," the other end of the horse is hinged to the dam foundation immediately below or at the down-stream edge of the main sill in such manner as to enable these movable parts, when lowered, to rest securely behind the sill. As used on the Ohio the wickets are 3 ft. 9 in. wide, varying in length from 9 ft. 9½ in. to 17 ft. 10½ in. The longest wickets are in Dams No. 2 and 3, nine and eleven miles, respectively, below Pittsburgh. All of the larger wickets are 12 in. thick below the middle support, tapering toward the

top to 9 in. at crest of dam. They are spaced 4 ft. center to center, leaving 3 in. spaces between them to avoid interference during maneuvers, to prevent the accumulation of excessive head when raising the dam, and to permit the more exact regulation of the pool. When rendered necessary, by reduced discharge, the spaces are closed with wooden needles, usually 4 in. square. The prop is supported by and travels on a cast iron hurter having two channel tracks or runways. The main track is in direct line with the prop and is obstructed by the fixed step for its support when the dam is up; the side track conveys the prop around the fixed step when lowering the dam.

The modifications or improvements made in constituent movable parts of the Chanoine dam during the past 20 years have been few, although in most instances, important. So far, only wooden wickets have been used on the Ohio river dams, notwithstanding there appears no good reason why a suitable iron wicket could not be designed. Formerly they were constructed of a heavy wooden framework with interior panels of 2 in. planks, while the more recent wickets are built of the same thickness throughout their width, either of three or of four timbers running longitudinally. The prop was originally designed as a round shaft for the upper half of its length, while the lower half was much heavier and flattened vertically, but retaining the thickness of shaft above, resembling in appearance the old style paddle-shaped oar. Just what was the purpose of this peculiar design is not clear, since a uniform distribution of metal, practically in the form of a round shaft recently experimented with, apparently affords a much more rigid and desirable prop in every way. Except to build them materially heavier, and very recently to slightly alter their internal bracing, no changes of consequence have been made in the construction of the horses.

The most valuable improvement is probably that made in the hurter, introduced in several dams, and which has been sufficiently tested to indicate its worth over the old Pasqueau

hurter in use at Davis island dam. That hurter was designed to be set on the top of the dam foundation, and provided a very narrow extension for carrying the prop after its return to the main track or runway. Consequently, there was continual trouble in retaining the prop on the hurter, and when off, not only required considerable time for replacing, but almost invariably resulted in more or less injury to the floor of the structure. The new hurter has practically overcome all of these objections. Its down-stream half is trough shaped, grad-

Chanoine wickets in the "raised" position in the 700 ft. navigable pass at Dam No. 2. These wickets are 17 ft. 10½ in. long and are probably the longest wickets in existence.

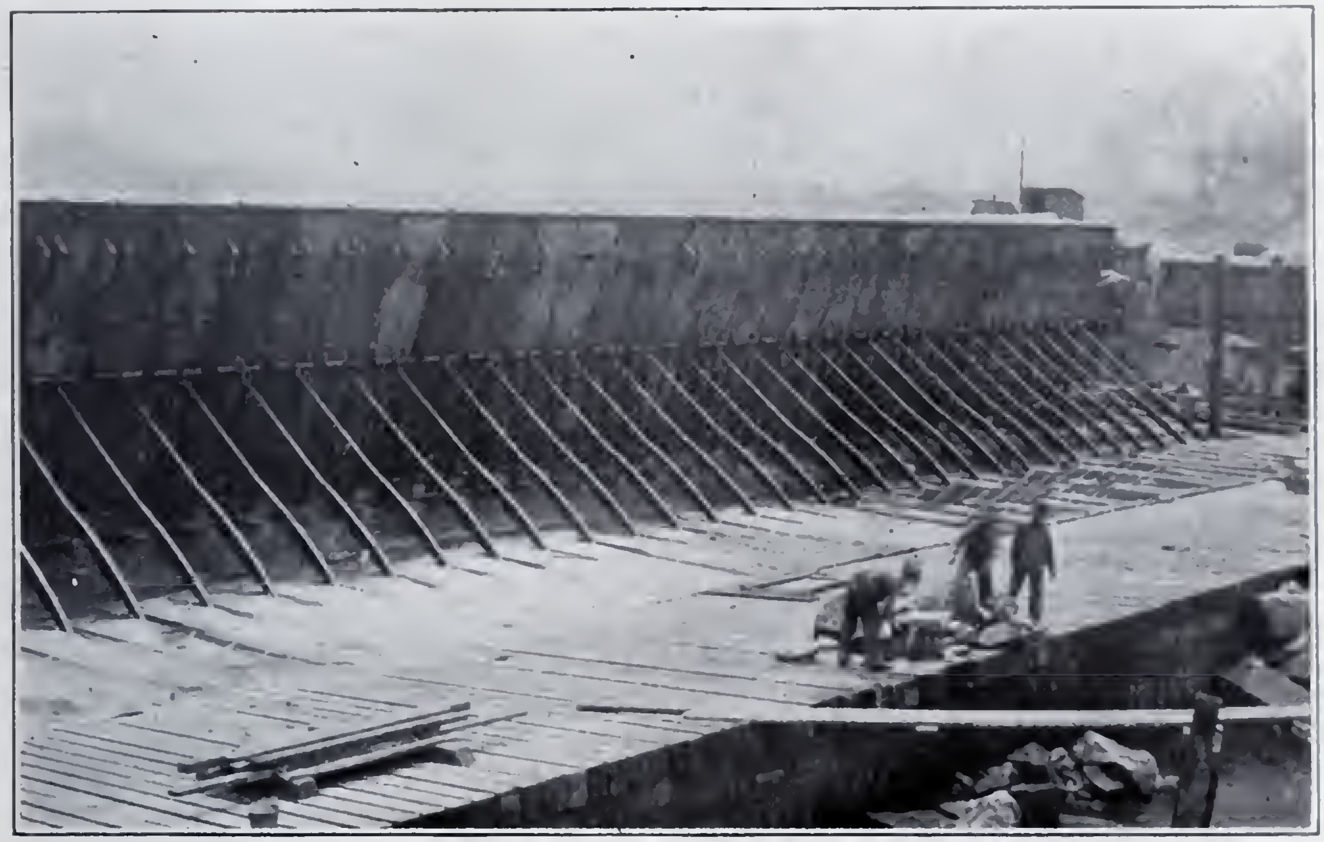
ually widening from the fixed step or main prop support to a width of two feet at the lower end. When set, the top edges of its guard walls are in the plane of the dam floor. This renders it almost impossible for the prop to leave the hurter altogether and, in the event of such an occurrence, makes its return much easier.

Instead of the original timber floor spiked to a heavy wooden framework partly encased in concrete, the present foundations are constructed entirely of concrete with steel anchor beams for supporting the sills and wickets. These foundations are quite similar to those constructed for fixed dams and, where rock foundations are not available, consist of concrete supported by bearing piles, triple-lap sheet piling being driven along the up-stream edge to prevent under-leakage. Cast iron dam sills have also been seriously considered, but until now only wooden sills have been used.

Doubtless the most flagrant oversight in the first movable dams on the Ohio consisted in the failure to provide proper protection against injurious scour below them, and against injury to wickets by ascending vessels. While some methods for preventing serious scour were tried on dams erected below Davis island, the first successful attempt at counteracting both of these defects was made at Dam No. 1, (Herr island), Allegheny river, by means of a crib, 20 ft. wide, adjoining the downstream edge of the dam foundation. The top of this crib inclines upward about 2 ft. from the floor of the dam to the elevation of sill. Its depth is 13 ft., and along its lower wall was placed a triangular prism of large, rough stone. After five years' operation, involving an unusual number of maneuvers at this contracted section of the river, there has occurred no injurious scour below the navigable pass nor, in fact, such as to require any attention whatever. In 1906, below one of the bear-trap weirs, where a slightly narrower crib exists, the scour extended to bed rock 42 ft. below lower pool level but apparently did not affect the stability of the structure. The scour was due to the long continued discharge, through the

crib, of frequently recurring rises in the river. The object of this construction is not to prevent scour altogether but rather, by deflecting the current upward, to carry its maximum effect beyond the danger limit. In consequence of its success in the Allegheny, this feature has been applied to the later Ohio river structures.

The most important improvements in the locks are: The elimination of hydraulic or pneumatic cylinders operating an



A partial view of Dam No. 4, on the Ohio river, showing concrete foundation, protective crib, and Chanoine wickets in "raised" position in a portion of the navigable pass. The wickets are 17 ft. 9 in. long by 3 ft. 9 in. wide. The photograph was taken during construction while the entire work was enclosed within temporary coffer-dams.

entire system of filling or emptying valves on one connecting rod, consisting of sixteen 4½ ft. circular butterfly valves, and the substitution therefor of individual jacks, each operating one valve either by air direct or by some other fluid delivered from the main power plant through pipe systems underneath the

locks; the discontinuance of the use of steam direct, owing to its enormous loss and the general inconvenience due to condensation, freezing pipes, et cetera, and substituting compressed air or oil; the use of steel lock gates having fixed axles with loose wheels, and a so-called lateral pendulum motion sufficient to withdraw them from all bearing surfaces when not sustaining the pool head, thus relieving them of all friction when in motion; and the adoption of concrete construction for all masonry, in place of stone.

The purpose of this paper, however, is not to enter further into the details of these works except, perchance, where material modifications from former construction have been made. It is the intention, rather, to direct attention to certain important features affecting the maintenance and operation of a series of large movable dams established on this great ice and drift-producing stream.

AUTOMATIC WEIRS.

When at least 94 per cent of the free-discharge section of a stream at a 6 to 7 ft. stage is being obstructed by setting up shutters to intercept its flow, it is obvious that a considerable head is being rapidly created, greatly increasing the difficulty of accomplishing its final closure. When, after its elevation, there remains only 6 per cent of the discharge area through a dam, it is equally evident that even small rises will materially affect the regulation of pools and render liable the loss of maneuvering control, should necessity require the lowering of the entire dam. Furthermore, owing to the physical difficulty experienced in accomplishing the closure or opening of dams under considerable head, it is manifest that some means should be provided for readily affecting an initial opening or final closure of moderately large width, operative automatically or with the least possible physical exertion.

The necessity for automatic weirs having been recognized as an essential feature in a system of movable dams for the systematic slack-watering of the Ohio, one or more such weirs

have been introduced in each structure erected. These are all of the bear-trap type because they fulfill the principal requirements to a greater degree than any other type, viz: Ample dimensions, both of width and height; reliability as well as facility of operation; comparative safety from injury, et cetera. Of the seven movable dams now in commission in the vicinity of Pittsburgh, (six on the Ohio and one on the Allegheny), each is provided with two bear-trap gates, except Dams No. 1 and 2 on the Ohio, which have one each. The lower leaves of

Lower half of steel bear-trap gate under construction at Dam No. 3, Ohio river.

the latter two alone are built of wood like all of their predecessors, except Dam No. 1 on the Allegheny and Dam No. 6 on the Ohio. Those in Dam No. 6 consist of heavy structural steel frames filled in with timbers; the rest are built of steel throughout. The upper leaves are practically alike in all of the gates, being comparatively flexible longitudinally, and constructed substantially of timber filling between I-beams or channels which usually form one member of the upper hinges.

Maximum rigidity in the lower leaf and minimum leakage in every part of the entire structure are the essential elements entering into the proper construction of bear-trap gates of the simple design here used. Friction, it is true, must not be overlooked, but it is not so important as the features mentioned and ordinary efforts to reduce it will produce satisfactory results. All of the wooden gates of considerable size and also the wood-filled steel-frame gates at Dam No. 6, while still serviceable, give unmistakable evidence of structural weakness and will undoubtedly not be long-lived. On the other hand, the steel gates first constructed at Dam No. 1 on the Allegheny river, and having now been in active service for five years, are exceptionally stiff, rising and falling, as far as can be detected, in a perfectly horizontal line. In addition to their stiffness, the steel construction also affords the advantage of requiring no initial head for raising, having ample air storage capacity to enable the gates to rise considerably above the water surface. Each of the eight existing steel gates has a width between piers in their undercuts, of 94 ft. 4 in., their vertical heights over sills vary between 10 and 13½ ft. The vertical height of the wooden bear-trap gate at Dam No. 2 is 14⅔ ft. So far, indications apparently favor the larger or higher gates as rising more readily than the smaller ones. However, no conditions have arisen under which the gates, working freely and properly supplied with air and head, have exhibited any disinclination to rise. In the event of purely local injury, steel gates will doubtless prove no more difficult to repair than wooden ones, and the only apparent evidence of superiority in

the latter is that of durability. Like all metal lock gates, bear-traps cannot economically be painted or otherwise protected from corrosion, and must be given over to the merciless action of our acid-laden waters. Should a gate be seriously damaged and fail to rise, provision has been made in all recently constructed dams for speedily closing the opening between the piers both above and below the gates with Poiree needles. These needles serve both as dams to sustain the pool during repairs and as coffer-dams for draining the inclosure containing the damaged structures.

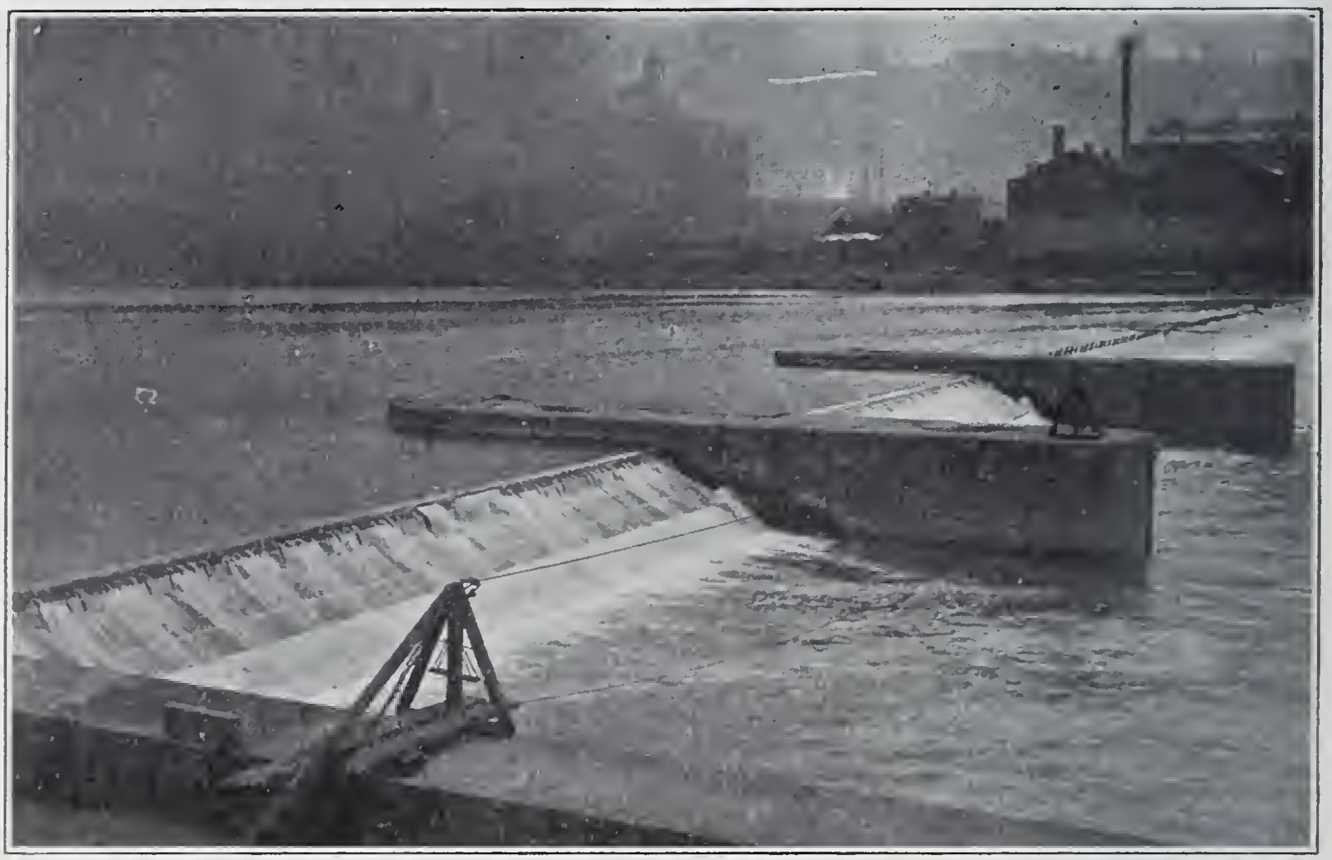
While the proper proportion of the total length of the dam that should be devoted to automatic weir is dependent upon many things, the question resolves itself into the determination of what will most efficiently, safely and economically regulate the pool under the varying conditions affecting the fluctuations of the stream, and properly conserve open-river navigation below while the dam is being raised. Experience with movable dams of various lengths has quite fully demonstrated that the shorter dams, having the greater percentage of automatic weir opening, are easiest to control and maneuver. Just why this should be so is not altogether clear, except that it may be attributed in considerable part to the fact that the shorter dams do not so nearly exhaust the physical energies of the operating forces. The main object of slack-water improvements being to subserve the interests of navigation, first having determined on navigable passes of least width consistent with the proper and safe passage of large coal fleets, every endeavor should be made to acquire maximum facility for successful operation of the structures as a whole, with the smallest expenditure of labor. As a first essential, then, ample automatic weir space should be provided.

On the upper Ohio the later dams each have 700 ft. width of navigable pass, two bear-trap gates, each 94 ft. 4 in. between pier undercuts, and the remainder of stream, generally not exceeding 200 ft., closed with Chanoine wickets. Although successfully used at Davis island dam, the value of the latter for

pool regulation in a large system of dams, is somewhat speculative. It is probable that fixed dams with movable crests, not exceeding about eight feet in height, would be more serviceable.

OPERATION.

The largest wickets in operation are at Dam No. 2, Ohio river, being 17 ft. 10½ in. long. One year's experience with them seems to justify the opinion that the economic limit as to maintenance and operation has probably been reached, notwithstanding the fact that the construction cost would be diminished by increasing the height of movable dams and reducing their number.



Dam No. 1, at Herr island, in the Allegheny river. Two bear-trap gates in the foreground, and a 500-ft. navigable pass in the distance, extending to the opposite shore. This dam has a 7-ft. lift, the view showing it in the raised position.

Heretofore, the operation of Ohio river dams has been confined to individual structures rather than to a series of dams forming a continuous navigation of considerable length.

Seven dams in consecutive order are now ready for operation, giving 35 miles of slack-water extending from Aspinwall on the Allegheny, to Merrill Station, three miles below Beaver, on the Ohio. Of these, Dams No. 3, 4 and 5, exclusive of their locks, largely designed and constructed under the direction of Major Wm. L. Sibert, were recently completed under the direction of Major H. C. Newcomer, Corps of Engineers, U. S. A.

In the successful operation of these dams as one system, some important questions, not materially applicable to the maneuvering of a single structure, will arise. The Ohio is a large stream, even at its head, and the meteorological conditions are erratic and their indications unreliable. Heavy reported precipitation above often affects no material change in the river condition, while at other times dangerous rises occur in advance of reports and while the rain is still falling. Moderate water-stage and weather conditions have existed at sunset in mid-summer, and before sunrise there has been sufficient precipitation to produce a 10 ft. natural stage of water, necessitating the entire maneuvering operations of all dams, together with the attendant preliminary preparations. Since such phenomena may recur at any time, they must be regarded as imminent with every abnormal rainfall until proven otherwise. On such occasions the personal factor at each dam is an all-important one. The operator must perform his work properly else the system as a whole fails for the time, in a degree at least, and navigation may become seriously impaired. As a general rule, the transformation form pool to open-river conditions, owing to rises, precludes the maneuvering of dams independently of each other, because of their intimate relationship through the intermediate pools. Although originally built for a 6 ft. navigation, the locks and dams have been so modified as to create a safe 9 ft. navigable depth in the pools. As a rise advances the pool slope increases. In disposing of rises in general, it will therefore be the aim to maintain the normal pool elevation at its head, gradually reducing it at the lower end

until the dams are down at a natural stage of approximately nine feet.

The second and, in the opinion of the writer, the most serious question involved in the entire subject of movable dams on the Ohio river, is that relating to the conservation of the open-river navigation below, while the dams above are

Raising the wickets in the navigable pass at Davis island dam. The hook of the hoisting chain engages in an eye at the bottom of the wicket which, with its "horse," is pulled up to the position shown, and held there securely by the "prop." The force of the current then catches the lower end of the wicket and swings it into an upright position.

being raised. The volume of water required to fill the seven pools, if the dams which are now completed be raised at a 6 ft. natural stage, has been approximately computed as 1 019-000 000 cu. ft. The hourly discharge, however, at that stage at Davis island dam is 100 800 000 cu. ft. Consequently, to raise even this small number of dams simultaneously at 6 ft. depth in the channel, filling the pools would require the entire discharge of the stream for a period of practically ten hours, and, assuming there was no leakage, would cause the river below the lower-most dam to become practically depleted for a length of perhaps thirty miles. With each additional dam this difficulty must necessarily increase. The proposition to raise the dams at a higher natural stage is met by the fact, that since it is impracticable to raise any of them at a depth of over about 7½ ft. on navigable pass sill, the evil would not be remedied, but merely transferred a little farther down the stream. On the other hand, to raise them at the rate of one or two per day would, at times, permit the water to become too low before recovering the pools, except those near the head. Whatever the method pursued, the pools must be filled, and the river below must be robbed of the amount of water required to accomplish the filling.

Naturally the question arises, "Does this not practically condemn movable dams for establishing a system of slack-water on large systems?" By no means. Without them or some other form of dam, during the summer season only a few days would elapse from the proper time for establishing the pools until the water would recede to an unnavigable stage; there to remain probably for weeks or months, with practically all navigation suspended. With a movable dam system, some inconvenience must necessarily be expected for the few days required to establish the pools, after which the best of navigable conditions should prevail until the dams must again be raised. Experience will quickly reveal that, by skillful maneuvering, much can be done to materially reduce the inconvenience to navigation. Again, should it be deemed necessary or

desirable, the situation could be greatly relieved by erecting storage reservoirs of moderate capacity on many tributaries of the Ohio for the purpose of replenishing the water loss sustained in open-river below the dams in process of raising, and of more quickly filling the pools above those already up. Furthermore, when it is realized that the number of times Davis island dam has been raised annually during the past 17 years averages less than five, the extent of this interference will not appear so unreasonable.

The lock at Herr island gorged with ice, which is packed solid from floor of lock and extends above the top of lock wall.

The quantity of discharge to maintain the leakage, lockage losses, etc., in such a system of locks and dams in exceptionally dry seasons, has doubtless been settled satisfactorily during the past 23 years' operation at Davis island. That structure is considerably longer than those below it, and while it has sustained an abnormal head prior to 1907, it has always maintained a normal pool, although on some occasions requiring some effort to do so. With a material reduction of head such as will obtain in a continuous slack-water system, no doubt is entertained that the water supply will be ample.

Perhaps the most lamentable objection that can be urged against the Chanoine wicket system of dams, adopted on the Ohio river, is that it is not well adapted to satisfactory operation by a maneuvering boat under ice conditions. While this is true in a general way, such dams have been lowered when frozen, without detriment either to the structure or navigation interests by first drawing the pool off gradually in advance of a rise. Doubtless some effort will yet be made for lowering such dams under unfavorable conditions, either from lock wall or pier, by means of an improved tripping bar or cable, or a car suspended from a cable. Any reasonable experiments in this direction will fully justify their cost in reduced operating expenses.

A special board of army engineers appointed by Congress, recently submitted to that body a favorable report upon the feasibility of permanently improving the Ohio river throughout, by a system of movable dams designed to provide a 9 ft. depth for navigation. The system proposed contemplates a total of 54 dams from Pittsburgh to Cairo. In addition to the six dams already completed between Pittsburgh and Merrill, the following locks and dams are in various stages of construction: No. 8, near East Liverpool; No. 11, at Wellsburg; No. 13, at Bellaire; No. 18, near Parkersburg; No. 26, below the mouth of the Kanawha river; No. 37, below Cincinnati, and a dam at the head of Louisville falls, a total of 13 locks and dams, or practically one-fourth of the whole number required to establish a continuous 9 ft. slack-water navigation over the entire river.

Heretofore, practically all of Pittsburgh's coal and iron fleets, forming the bulk of its down-stream commerce, have been transported in open-river, except on rare occasions when a few have passed through Lock No. 1. The usual tow for a steamboat of about 1000 h. p., is twelve coal-boats and perhaps two or three barges. These fleets are not generally increased until they pass Dam No. 13, at Bellaire, where another length, consisting of five coal-boats, is added. At Dam No. 6, the

gauge records show the average number of days annually, during which the stage is 9 ft. or over, to be 117 as compared with 79 days at Davis island, an increase of 48 per cent. The locks on the Ohio are 110 ft. wide by 600 ft. long between the gates, and at each locking will pass a steamboat and ten coal-boats, containing 10 000 tons of freight, without breaking the fleet. The boats draw about 8½ ft., while the normal depth of water provided on lower lock sills is 9½ ft. It will thus be seen that the difference between open-river and lock fleets is inconsiderable, while their make-up is almost the same. Under such artificial conditions it seems altogether probable that navigators, in order to gain the advantage of the increase in duration of the annual boating period, will harbor their loaded vessels

A view of Lock No. 6; the type used on the Ohio river; useful dimensions 110 by 600 ft. The flow of water into and out of the lock is controlled by valves in the bottom of the lock wall, which are located beneath the cover plates shown at the right of the picture. There are 16 filling valves located above the dam, and 16 emptying valves below; opening the former and closing the latter fills the lock; reversing the process empties it.

in the lower pools, as far as practicable, there to await navigable conditions in the un-slack-watered river below.

During seasons of drought rises frequently occur which lack just a little of furnishing the depth necessary for the movement of deep-draft vessels. With 35 miles of artificial waterway averaging 12 ft. depth in the channel, controlled by movable dams which can be partially or wholly lowered in two to three hours or as much longer period as may be deemed advisable, such scant or inadequate rises may be made to give the required height and be so maintained for a sufficient length of time to permit of a heavy run of freight. Hence the improvement now completed above Merrill will have already materially lengthened the aggregate period of navigation, to which each successive structure will add perceptibly for the through shipment of heavy bulk freight.

DISCUSSION.

Vice-President Barnsley: Gentlemen, I am sure we are all very much indebted to Mr. Arras. He has presented a fine paper, and I have no doubt many things in it will bring to your minds certain suggestions in relation to the subject, and it will be very interesting to us all to have a general discussion.

Col. T. P. Roberts: One gentleman spoke about the tows not being able to pass on the river, especially tows like those of the Sprague, which are Mississippi fleets. The largest fleets leaving Pittsburgh are only 10 000 to 15 000 tons, which they enlarge at Bellaire, and again at Louisville, and sometimes at Cairo.

But it is my opinion that we will not have those large tows hereafter. With the improvement of the river, there will not be the necessity for risking such an enormous fleet because the river will be more uniform. I think it can be demonstrated that there will be money saved with smaller tows, and with less money invested in steamers. We have about 3500

boats at present and probably not more than a third of them are loading at one time; some of them only make a couple of trips in a year to New Orleans. Consequently with more frequent and regular service, the commerce of the Ohio river will be wonderfully better in the future, the number of barges in fleets down stream should not be greater than the number of empty or partially loaded barges which can be pushed up stream at a fair rate of speed. The large fleets with their very costly towing steamers, $100 000 to $120 000 each, were the outgrowth of the necessity of doing the year's business from Pittsburgh in less than 90 days' time scattered throughout the year, leaving 275 days idle. A couple of years ago I took part in a careful study with Maj. W. L. Sibert, which we thought resulted in a demonstration of the fact that, with a reliable 9 ft. depth on the Ohio, upward as well as downward shipments in tows of medium size between Pittsburgh and New Orleans would be practicable at lower rates than heretofore known on the western rivers, fully equalling the remarkably low up-stream rates on the Volga, in Russia, when that river is at its most favorable stage.

Chairman: We will be glad to hear from some of the people who span the river with bridges. I will ask Mr. Morse to participate in the discussion.

Mr. E. K. Morse: Mr. Speaker, it was not my intention to enter into the discussion of the subject this evening, as my views are not in full accord with the question, "Locks and Dams for the Ohio River." The building and maintenance of the locks and dams on the Monongahela river have been of untold value to this community. The building and maintenance of the locks and dams on the Ohio river, for a limited distance below Pittsburgh, will be of great value to the interests of navigation, but to join into the cry, "On to Cairo," in the extravagant sense in which it has generally been used, does not appeal to me in the least. Perhaps it is because I am not a navigator on any of our rivers; having been interested all my life in the use and investment of private capital, I am some-

what like the banker who wishes to see safe interest before investments are made. I have been educated to study propositions from their definite earning basis and to that end investigate carefully all the pros and cons before reporting on construction of works of like magnitude.

The Government is urged to expend millions of dollars in locks and dams. I do not wish to be understood as not approving of this, but in part I do, and in part I do not. With the statistics the Government has seen fit to print and send broadcast through its Agricultural department, it would certainly seem to me the part of wisdom and good sense to not start any new locks and dams until these great subjects of inland water navigation have been thoroughly investigated and decided upon. It is but very recently that I read, with great interest, the report of Mr. M. O. Leighton, issued from the United States Department of Agriculture, March 7, 1908, Circular No. 143. This report takes up and discusses the question of holding flood waters back by the use of impounding dams at the headwaters of nearly all the smaller streams entering into the Allegheny, Monongahela and other rivers which flow into the Ohio. We are especially interested just now in this vicinity in controlling the floods that have caused the loss of so many millions in Pittsburgh and vicinity within recent years. If, as Mr. Leighton claims, these floods can be reduced from 10 to 25 per cent by building storage reservoirs or impounding dams at the headwaters of the Monongahela and Allegheny rivers, thereby reducing the terrible loss through floods, and letting out sufficient water during times of dry weather to maintain a steady stage of water sufficient to provide power for large power stations, four great objects will be obtained and the solution of four great problems will be the result. First, the reduction of floods; second, maintenance of navigation; third, obviating the necessity of additional dams; fourth, revenue from power at the site of dams. If the millions which the Government is spending for locks and dams, and the untold millions that certain navigators insist upon the Government

appropriating for the Ohio river, were invested by private enterprises, it is inconceivable that a corporation would go ahead and build additional locks and dams without a most thorough investigation of the whole subject. I maintain that the Government should treat this matter just as a private enterprise would.

I have been impressed in listening to the paper of the evening with one fact that goes home to me very closely. It is with what delight the rivermen hail the construction of a dam which has a navigable opening of from 700 to 720 feet between piers; but let me submit plans for a bridge anywhere on the Ohio river with the channel piers located for a 700 ft. span—no matter what my rights are, no matter what the advantages and proper claims may be for those who want to cross over bridges, it makes no difference how imperative it is for the welfare of the communities, or how necessary the joining of two great commonwealths—we are treated as a menace to navigation and looked upon as a nuisance. This arrogance on the part of certain navigators of the Ohio river has become more and more pronounced as the Government has favored them with millions of improvements, until today any bridge structure is looked upon as such a menace to navigation that certain rivermen have assumed the responsibility of asking the Government to condemn the location of any bridge unless the span is 750 to 800 feet or more in length. It makes no difference whether it is on a curve or a straight run in the river—it is a nuisance and a menace to navigation. I will admit that everything that is placed in the river is a menace to certain navigators.

In December, 1872, there was passed what is known as the Ohio river bridge law which prescribed the method to be followed in the construction of bridges over the Ohio river between Pittsburgh and Cairo. It has been a good law; it has been amended from time to time, and will be amended in the near future. I say "will be amended" because no class of people is going to permit themselves to be taxed for any one stream

and have those, who derive practically the sole benefit from the same, attempt to domineer and dictate to the public as they have in the past and are doing today. I have always tried to meet the navigators half way and have been fair, but am now beyond the limit of endurance. I believe that if the navigators are to own the Ohio river, it is high time that the Government should charge a toll for coal and other merchandise down the river, and a very light tax, merely a nominal sum, for pool boats and craft navigating the Monongahela and a portion of the Allegheny rivers.

In using as strong English as I have, relative to the construction of bridges, I am only speaking from personal experience, and I have only come to this conviction after years of bridge construction on these rivers, and what I have said is only the reflection of the treatment received at the many bridge hearings I have attended.

Mr. J. N. Chester: Mr. Morse has covered the ground very fully, and while we have had no trouble with bridges, we sometimes feel, when we appear before the Government engineers for permission to build a water supply in-take in the river, that navigation is paramount to pure water and everything else. We find exemplified at such times that every man's enthusiasm for his own work is almost unbounded, precludes the light form coming in, and shuts out entirely his ability to recognize the rights of others. Such experiences, however, have not been met with in this district. We had an instance once, in the Red river district in Louisiana, where we were prevented from doing anything to better the water supply because it was an impediment to navigation. This was just above Shreveport. There was only one boat a week and that a small huckster plying between there and Fulton, making one round trip a week, but the boat had to be kept going whether Shreveport had any water or not.

The navigation of our rivers is no doubt of much importance, but I agree with Mr. Morse, that those who make use of the privileges ought to be taxed a reasonable amount to

maintain them. In other words, I have never been able to see why the United States Government should undertake to build a traffic way by improving the rivers and throw them open free for all, any more than that they should lay down a railroad track, and give certain parties the right to run their trains over it free of tolls and free of any of the expense for maintenance.

Mr. Jas. P. Leaf: I don't like to take exceptions to what Mr. Morse has said, but the government claims to own these rivers and I don't see why they should not keep them up. The government spends a good deal of money in improving its harbors, making them suitable for navigation, and has made an excellent system of navigation on the lakes. Improvements on the lakes were installed very early when there was very little commerce, and they have developed a wonderful traffic. I believe that the Government has started on a development of inland water ways that will not only surprise us all but will benefit this country very much, and that before many years. The state of New York found it very much to its advantage to improve the canal from Buffalo to the Hudson river and make it a 12 ft. stage at a cost of $101 000 000, and I believe that the next ten years will find more work done in the improvement of the rivers and harbors than the United States has done in all time previous. They are building the canal across the Isthmus. All the great water-ways that have benefited the whole world have been completed in our own age—the canal at the Isthmus of Suez, the canal across the peninsula of Greece, the improvements on the Great Lakes and the improvements on the rivers.

I would like to ask, if the ship canal from Pittsburgh to Lake Erie should be built by a private corporation on a 12 ft. basis, could the river be improved by dredging the upper end of each pool to make it navigable to Pittsburgh without building a canal paralleling the river for ship canal purposes?

***Mr. Jas. G. Geegan:** I have listened very attentively to

*Non-member.

the reading of the paper and it contains much information a river man ought to know. Of course one must admit that the whole project of the Ohio river slack-water system is a large one, gigantic in fact, and that there is more or less cause for the question to be raised, "Will this expenditure of millions of dollars in locks and dams give to the people of this nation sufficient return for the money invested?" The whole proposition of the "On to Cairo" movement becomes almost unlimited in scope in the various phases of our national life; the commercial, the economic and, to an extent, the social. It touches the economic in that it provides some three thousand or more miles of national independent transportation facilities, which can not be capitalized by private individuals nor usurped by trusts. It touches the commercial in that it provides the cheapest possible transportation system known to the uses of man. It touches the social in many ways, but particularly in that it provides a great defense for the people—a highway for warships or gunboats during internal or external strife.

At least one-third of our entire population will be benefited by this movement; benefited, not only in that they will have cheap transportation facilities for their commodities, but in a manner more valuable to true American principle, they will be independent of railroad trusts or other transportation monopolies that now exist or may exist in the future.

One of the gentlemen made a remark about a railroad keeping up its right-of-way. Why should it not? The railroad owns its right-of-way with all the necessary equipment to carry on its business and to which an individual has no right. A private individual can not travel on a railroad with a hand-car, to run it how or where he will, or make any destination he pleases. A man may go any where he pleases on the river, or he may get a steamboat and become a competitor in any kind of transportation; he may become an operator on the river and carry his coal or iron where he will. That to my opinion is the way for the people of this nation to compete with the railroads or with any other kind of transportation that may

become a monopoly. The cost of transportation by river is very low compared with the rate by rail. I have been advised, and I believe on good authority, that a local interest tows its coal from Pool No. 4 to Pittsburgh at a cost of about four cents per ton by river—and that too on a stream where the lockings are limited to a certain extent—whereas the coal tariff rate by rail for the same distance is 33 cents per ton. At that rate it does not take long to total up a lot of money, and it can easily be figured out what the vast tonnage on our rivers would save in a given time. Where the locking will permit the tows to be made larger, as on the Ohio river system, the cost per ton per mile would of course be less. At the rate of saving above referred to alone it would not take a great while to pay for this investment. Take for instance a tow of the "Sprague:" I dare say the actual towing cost on coal would be about 50 cents per ton from Pittsburgh to New Orleans, while the railroad rate, I believe, is $4.50 per ton; but here I am not speaking of actual knowledge or experience, but rather from hearsay, the business of our company being confined to the local market. I do know something, however, about pool towing, and the figures above given, of 4 cents per ton against 33 cents, are approximately correct. The locks and dams being under Government supervision, there are no dividends, as there would be if they were private enterprises; the dividends go direct to the people. I certainly favor a continuance of the work of improving the Ohio and its tributaries.

Mr. Chester: The transportation made possible by the improvement of the rivers is the best argument why the river shippers should pay something. I do not want to go on record here as being opposed to river improvements. I believe the Government did right when it subsidized railroads in the west and enabled them to build through an open country and develop it, and I believe some such plan is the proper policy to pursue in connection with our rivers. I was very much gratified, ten or fifteen years ago, to see the Columbia river made navigable so far inland, and into territory that no one

at that time could say could possibly pay a fair return. But it was developing the country and affording transportation where there was none. Some provision should be made, just as they are now making in the reclamation service, whereby those enjoying the benefits of that expenditure should contribute something toward wiping out the indebtedness incurred in building the improvements, and the constant paying of interest thereon. The way to look at it is, "What is the man out in Illinois getting out of the money spent on the Ohio river?" The burden can be distributed, as it was with the railroads, in the way they are now distributing it in the reclamation service.

Col. Roberts: The matter of tolls is a question of economical more than of engineering interest; but as it pertains to a National policy it is worthy of careful consideration.

If it be true, as contended by some, that the railways can handle every species of traffic no matter what the distance between points of production and consumption, better than could the improved waterways, it would be a manifest absurdity for the people to be called upon to pay for the construction and maintenance of water-ways. The majority of the people of the country, as represented in Congress—including some prominent railroad officials—and the ablest of our professors in the new department of transportation, entertain the belief, however, that the railways as a whole system could render more efficient service to the public if they could be relieved of their lowest classed freights, such as ore, fuel, building materials, etc. It has been found, in both France and Germany, where canals and improved rivers most abound, that by assigning to the water-ways the low grade freights, the more valuable traffic on the railways increased more in value and profit; or, in other words, their loss by reduction in gross tonnage resulted in a financial gain.

It was found necessary, however, for the governments to undertake the construction and maintenance of the waterways, and in Europe they now have this complementary sys-

tem of transportation, one practically free, and the other maintained by toll charges.

So it is coming to pass on this continent of different climates and natural productions, with vast distances separating different classes of producers, if the interchange of commodities is to keep pace with the demands for them, every means possible must be resorted to to regulate and cheapen the cost of transportation. What benefit is it to the railways between Western Pennsylvania, Eastern Ohio and West Virginia, and the Gulf states, if sugar and rice from Louisiana and Texas must take the sea route to New York to reach us. Or, what advantage is it to the people of the Ohio valley to ship their manufactured products to the Orient, via New York, to reach Panama, when, with an improved water-way to the Gulf, the goods might go cheaper that way. Surely the people of the interior of this great continent will not forever be able to overcome the handicaps which are gradually tightening about their industries to the betterment of competitors.

It cannot be disputed that the water-ways from the interior to the seaboard should be under the control of the Government, but no money should be spent upon them unless the people have reasonable assurance that the general welfare is to be conserved by the improvements made. If, in the future, the traffic on them will bear a toll, no one should object to its imposition; but let us first complete some of the projects before discussing the matter of tolls.

On the work already completed on the Monongahela river there is visible more than a glimmer of profits reverting to certain shippers who might well afford to pay toll charges; but I take it that as the Government builds light houses, and deepens lake and ocean harbors about our leading cities for the benefit of commerce, it will be reluctant to make "fish of one and fowl of another" of its public benefits. Those wise enough to take advantage of the river improvements and reap the profits they are reported to make, are doing a good thing by demonstrating the value of the public work. More will fol-

low their footsteps as the path is made safer and longer.

Chairman: Mr. Arras, will you say something in closing the discussion?

Mr. Arras: The discussion having drifted into questions relating to the propriety of the Government prosecuting the public improvement of our national highways, free of tolls, I will confine myself to some specific questions asked during the evening concerning certain features of movable dams.

First, as to whether or not the improvements already made on the upper Ohio river will permit of such modification as to accommodate a 12 ft. navigation between the Beaver river and Pittsburgh, should a ship canal between Lake Erie and the Ohio (at Beaver) be constructed. This question was taken into consideration when the changes in the present dams from a 6 to 9 ft. navigation were determined. To secure this additional three feet depth, either the superstructure of each lock and dam was raised three feet or the lock floor and lower sill were lowered that amount, and the head of the pool deepened by dredging. It is therefore entirely practicable to resort to the remaining alternative in securing a second three feet additional depth by raising the superstructure, where in the former case the lock floor and sill were lowered. This disposes of the more serious question of passing the locks under pool conditions; but dredging at the heads of the pools must necessarily be performed in order to gain the required depth between structures.

In applying pneumatic lifting force to the raising of bear-trap gates, the air is transmitted into the interior of the lower leaves, which are built with 3/8 in. upper and lower steel skins and are comparatively air tight. As the volume of air increases in the interior of the leaf, the water is expelled through open man-holes in the under skin near the hinge line. Thus, as the gate rises, the air seeks the higher level at the free end of the leaf where the surrounding water exerts its greatest lifting force. The bear-trap gates at Herr island dam were proportioned on the basis of the Chittenden-Powell formula—the

ratio of hydraulic lifting force to downward pressure being as 100 to 80. Those recently completed at Dams No. 3, 4 and 5, Ohio river, are in the ratio of 100 to 66. The larger gate in Herr island dam, with a vertical height of twelve feet, weighs 95 tons exclusive of its water displacement, or about a ton per linear foot of gate between piers. The Ohio river steel gates, having a somewhat wider base, are slightly heavier.

In addition to the change in width of base just mentioned, but few alterations have been made from the gates first constructed at Herr island. Instead of flat plates supported by interior bracing, buckled plates were introduced in the Ohio river gates. The flexible air connections at the lower gate hinge, which at Herr island are within a curved water seal at the lower hinge axis and therefore quite inaccessible for repairs, have been placed entirely outside of the upper skin and protected with heavy cast steel coverings. Of the modified gates, only the two at Dam No. 5 have been tested, and indicate that the changes are a material improvement.

Bear-trap gates, in addition to regulating the pools and disposing of minor rises, which is their principal function, are also convenient for disposing of masses of drift and ice. To avoid a repetition of the excessive drift disposal at each dam it is probable that measures will be taken soon with a view to its entire removal from the river at as many dams as experience may suggest. This will probably be accomplished by burning the drift either on boats equipped with furnaces or on the shores at the dam abutment.

For the present at least, a negative answer only can be given to the question as to whether or not bear-trap dams can be utilized throughout entire structures having wide navigable passes and weirs. Assuming that it is practicable to provide ample power for the initial raising of long sections when in perfect working order, the embarrassment that would inevitably follow their failure to rise because of some trifling interference, the difficulty in determining the probable cause of such failure, and the delay and expense due to repairs when

necessary, will probably long stand in the way of their use in long sections. Furthermore, were the practicability of their reliable operation in any length beyond dispute, there can be little doubt that a 500 or 600 ft. pass instantaneously lowered would create such an enormous wave as to prove destructive to navigation interests for a considerable distance both above and below. It is believed, however, that much advantage is to be gained in dividing the automatic weir space into gates of different lengths, the maneuvers of which can be suited to the exigencies of the case.

Like the needle dam, invented by M. Poiree in 1834, the Chanoine dam also derives its name from that of its inventor. The fixed parts of the Chanoine dam, permanently attached to the foundation, are: The sill for supporting the wickets at the bottom, the horse-box for confining the lower axles of the horses, and the cast iron hurter supporting and regulating the movements of the prop. The movable parts, or wicket, comprise the shutter, horse and prop briefly described in the body of the paper. The movable parts when the dam is down lie folded together behind the sill. When the dam is up the shutter stands at an inclination of about 20 deg. or less, from the vertical, the horse nearly parallel to the shutter, and the prop at an angle of 35 to 40 deg. with the horizontal. As operated on the Ohio river, a maneuvering boat—consisting of an ordinary 22 by 60 ft. scow with 3½ ft. gunwales and equipped with a strong hoisting engine, outrigger sheave, derrick and steam capstan—rests against upper edge of the wickets. By means of a specially designed hook attached to a long pole, the operator grapples the handle plate at up-stream or bottom end of the wicket, which is drawn upward until the prop drops into the fixed step in the hurter. The up-stream end of wicket is then pressed downward until the current swings it into position against the sill. To lower the wickets a slightly different hook is used, with which the handle at the top of the wicket is grappled and the wicket drawn up stream until the prop drops into the sliding step in the hurter, when it is re-

leased and falls into position, together with the horse and prop, behind the sill. When maneuvered from trestle service bridges the same operation is performed, except that, instead of hooks, chains fastened to the wicket handles are used.

Needle dams are so called because the curtain or screen retaining the pool is composed of wooden spars set contiguously across the stream; a sill at the bottom, and the bars resting against trestles at the top. The trestles turn in hinges on the floor of the dam behind the sill which protects them from injury when down. For the higher dams the trestles are usually spaced about four feet, and for the shorter ones as much as eight feet. Usually the needles are placed or removed with derrick boats moored above the dam. Needle dams are especially adaptable to streams with small low-water discharge. Chanoine wicket dams, on the other hand, require a large discharge in order to overcome the leakage.

In the more recent dams constructed in the Ohio river the foundations have been built of monolithic blocks of about 30 ft. length. To obviate the danger of settlement of a monolith it would seem that the older continuous or layer concrete foundation construction offers some advantages.

Chairman: Gentlemen, I wish to say that, while this subject naturally brought out some differences of opinion as to policy, I do not regret that the discussion has followed that channel. New policies are being formed constantly.

I do not regard this discussion as being among people at all diametrically opposed. It is a good healthy discussion which brings out the best thought and suggests the best thing to do in the future. Naturally the engineering profession will think out the best ways to overcome new difficulties, and it would not be well for every member of the Society to think alike; if so, we would not derive any good advantage in being incorporated into a society. Good-natured healthy discussion is very essential to our development, and I am always glad to see it.

Contributed: "In reading this paper one is impressed by the great responsibility placed upon the engineers in charge of the navigation structures of the Ohio river. A more complete appreciation of and respect for the work of those identified with the original design and construction of the dams is thus extended to those who rarely see them. It is evident here, as in numerous other works of a similar nature, that no schematic or thoroughly digested plan of improvement has been considered. So far as known, not even a complete survey of the Ohio river has been made. The general physical characteristics are known as outlined in the paper, but this is inadequate for a comprehensive study, much less upon which to base the plans of public works involving the outlay of millions of dollars.

In the paper we are told that "no exact measurements of extreme low-water discharge of the Ohio at its head seems to have been made," and it is doubtful whether any but the most fragmentary and isolated flow-measurements are available. This seems to be sufficient explanation for differences in the design of the dams. The lack of technical data is doubtless due to contingencies beyond the direct jurisdiction of engineers. But such an extensive undertaking as the canalization of the Ohio river is beyond the purview of any individual man and should be the work of a permanent National commission composed of experienced engineers.

In addition to the navigation of the Ohio river, the interests of Pittsburgh are very much concerned with the relation of the permanent improvements to the highest flood-water level. As a tentative suggestion and without the technical data at hand, the writer would venture to suggest that this level would be reduced by a lowering of the natural submerged dams; i. e., by dredging the river bed to a uniform gradient between the fixed sills of Herr island dam and Davis island dam. There is said to exist two such submerged dams or bars, one near the juncture of the Allegheny and Monongahela with the Ohio, and another at Glass House ripple. Then the pres-

ent water-way between harbor lines would be increased in cross section and the total discharge augmented by the corresponding increase of slope and velocity, the influence of which would be to give relief to the water impounded by the submerged dams and lower its general level.

The broad engineering problems involved in the management of the Ohio river afford opportunity to the best talent available. But first, there must be extended surveys, observations and records of all physical data to be followed by consistent treatment."

ROBERT A. CUMMINGS.

June 8, 1908.

Before the Structural Section, May 5, 1908

Chairman E. W. Pittman

Presiding.

WIND BRACING IN BUILDINGS.

By Arthur L. Bobbs,*

Member.

The building laws of the principal cities are nearly uniform in their requirements for wind bracing in buildings of great height as compared to their least width. Much has been written on the two-column or single-panel type of bracing, but very little has appeared on bracing extending through two or more panels. The usual practice has been to brace odd panels, rather than a continuous system. The determination of wind pressure stresses in a frame acting as a whole is more or less of an approximation, because the exact distribution of the stresses is unknown.

A common method is to consider the frame as a cantilever beam uniformly loaded, the columns acting as flanges and taking a part of the vertical reaction of the frame proportional to their distance from the neutral axis of the bent; each column at the same time taking $\frac{1}{n}$ of the horizontal shear or accumulative wind load. This is not only a very laborious method of calculation, but is incorrect, one assumption contradicting the other as will be shown.

Fig. 1 represents a three-panel bent, 30 ft. wide and with 20 ft. story heights, loaded as shown. The vertical reaction of the top story equals

$$\frac{4000 \times 20}{30} = 2667 \text{ lbs.}$$

The moment of this reaction about the leeward column equals

$$2667 \times 30 \times 12 = 960\,000 \text{ in. lbs.}$$

*With Milliken Bros., Inc., No. 11 Broadway, New York City.

Assuming the columns to be of 1 sq. in. in cross section, and their distance from the neutral axis 60 in. and 180 in. respectively, as in fig. 2, the moment of inertia is found to be

$$2 \left\{ (60^2 \times 1) + (180^2 \times 1) \right\} = 72000$$

The stress in the outer columns would then be

$$\frac{960\ 000 \times 180}{72\ 000} = 2400$$

while the stress in the inner column, x, is derived by the proportion

$$60^2 : 180^2 :: x : 2400, \text{ or}$$
$$x = 267 \text{ lbs.}$$

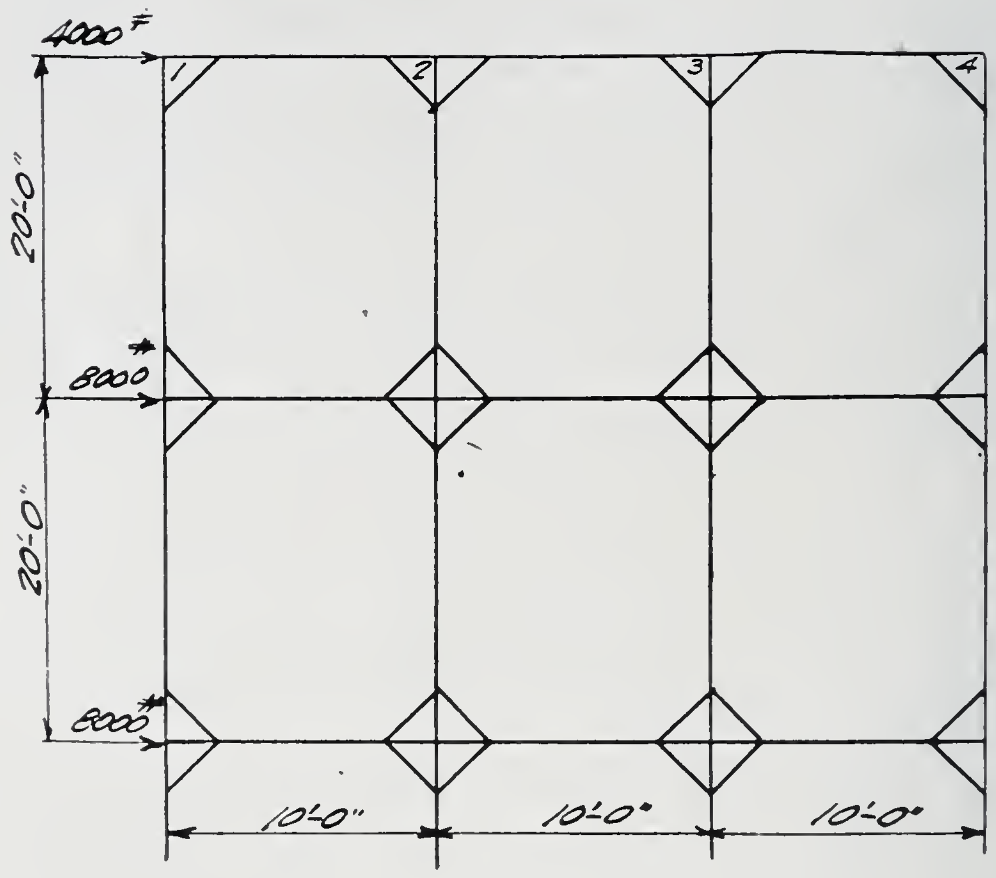


FIG. 1.

All connections being rivetted or fixed, with a point of contraflexure assumed to be midway between supports, and, as it is only the stress in the column above the point of contraflexure that affects the floor bracing, that point will be taken

as the centre of moments. The vertical reaction in the outer column at this point equals

$$\frac{2400}{2} = 1200 \text{ lbs.}$$

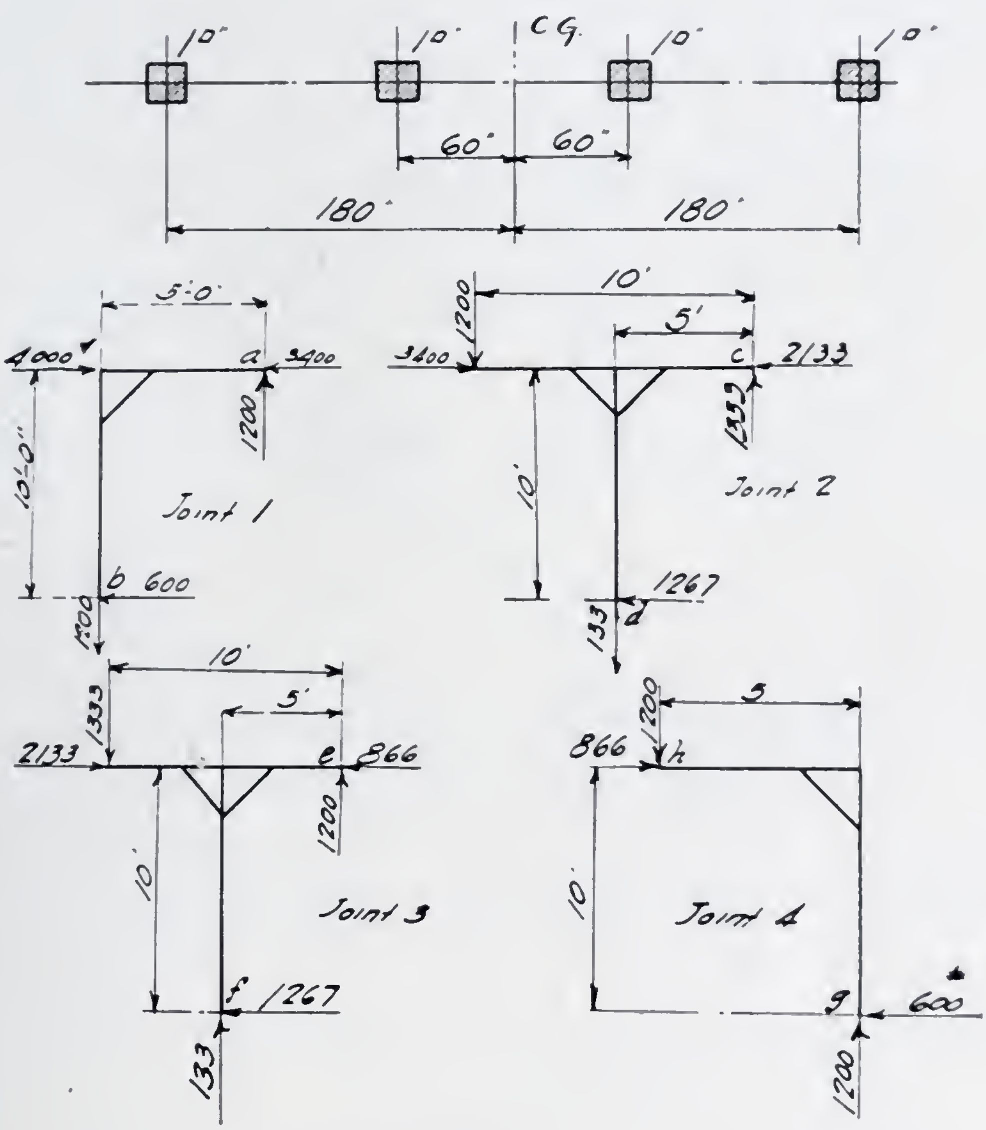


FIG. 2.

Taking the moments successively at points a, b, c, d, e, f, g and h (fig. 2) shows a greater force pushing against joint 4 than there is resisting it, causing relative motion.

Fig. 3, which is the same bent as before, will next be analyzed on the assumption that each column receives one-fourth of the horizontal shear. Taking the moments successively at points a, b, c, d, e, f, g, h, k, and l, shows the first and second windward columns taking all the vertical reaction, while the first girder takes all the vertical shear, leaving only

local or panel shear for the remaining girders. While this works out correctly, it does so unsatisfactorily, as it is practically a one-panel braced bent, with its vertical reaction obtained by dividing the moment of the wind force by the width of the whole frame. An assumption that gives a much better distribution of metal, and a more rational solution than the

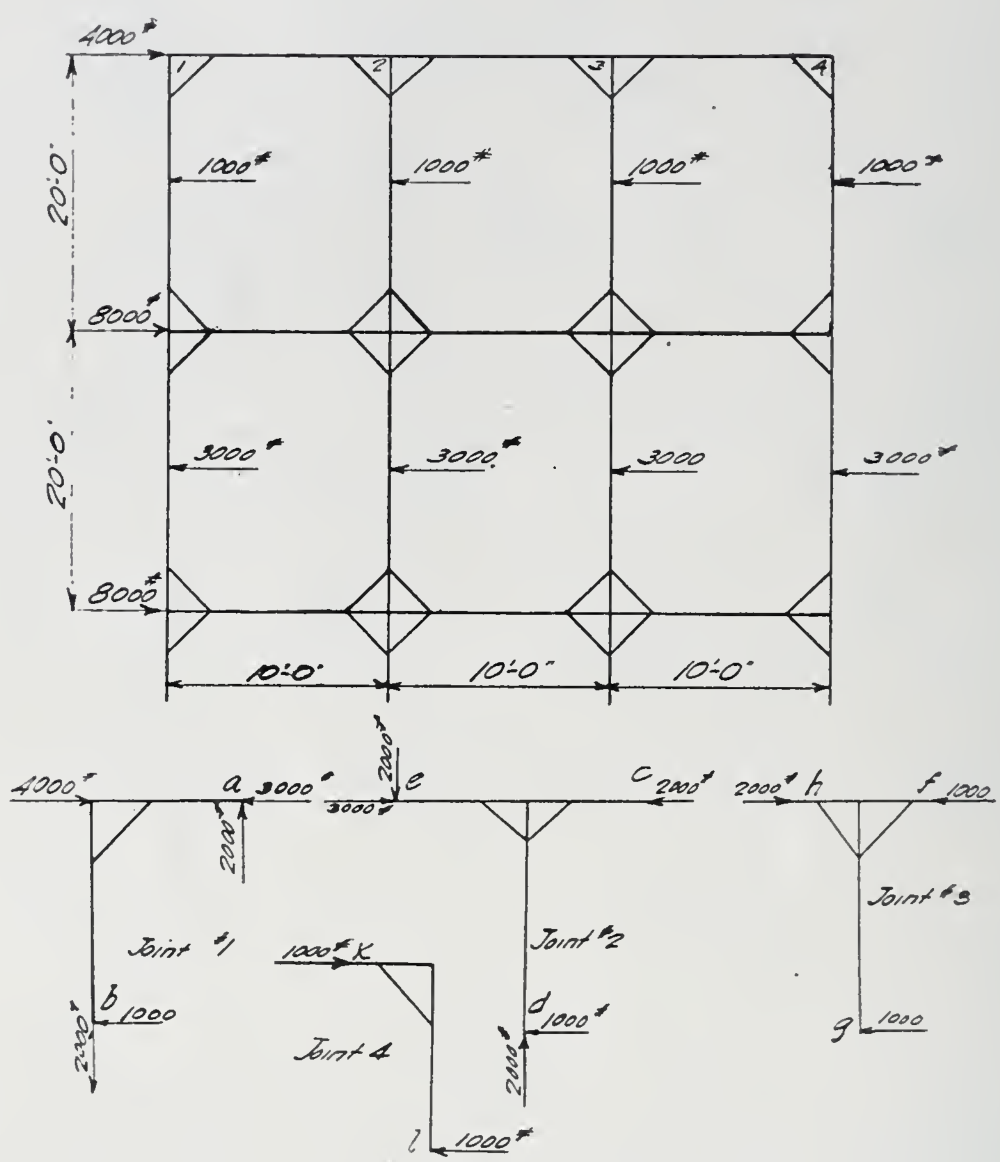


FIG. 3.

latter one, is to have the outside columns take all the vertical reaction of the bent and one-half as much horizontal shear as the interior columns, regardless of the number of columns in line, thus permitting the vertical shear in the girders to be uniform throughout, each girder taking an equal part of the total shear.

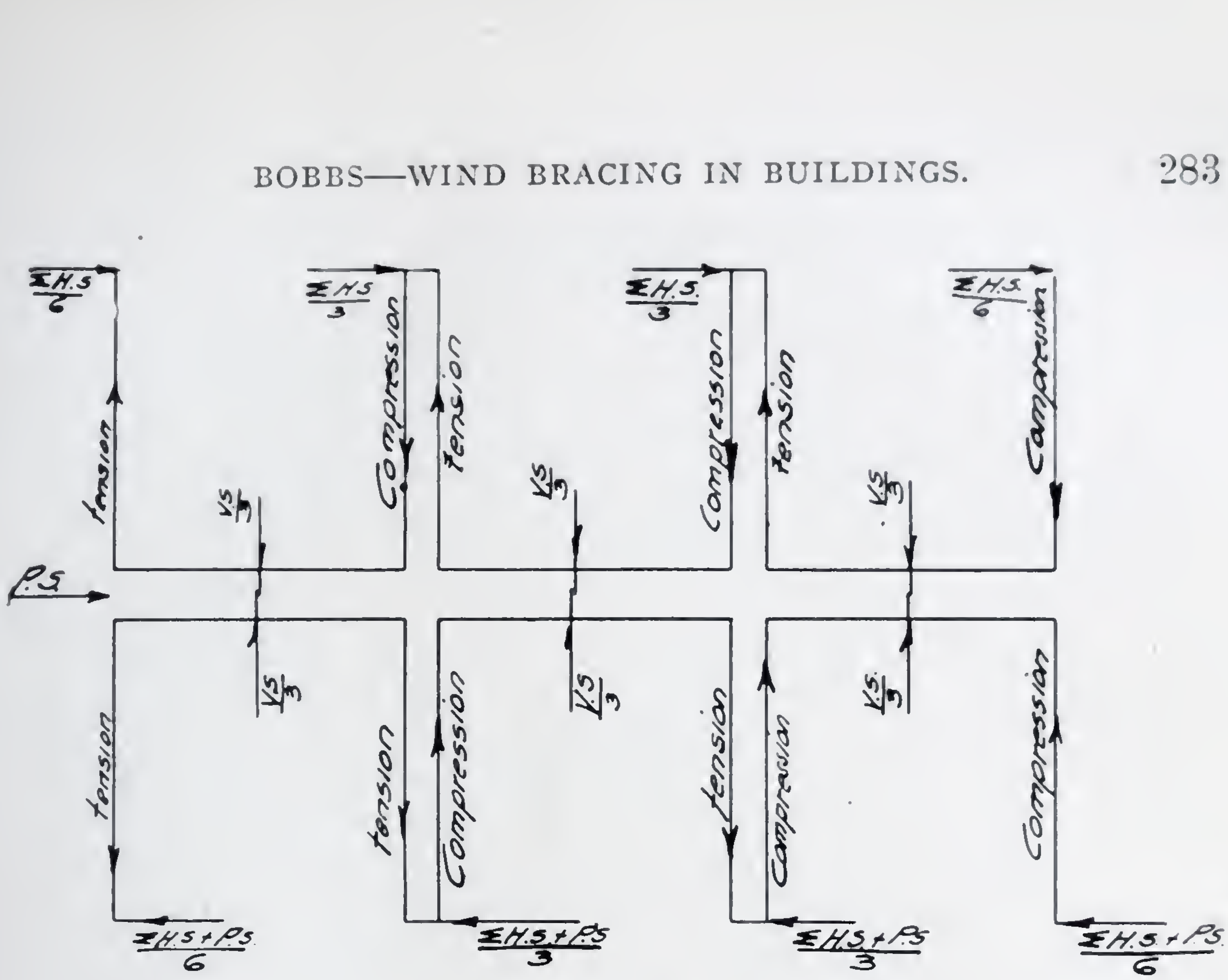


FIG. 4.

The interior columns have their vertical components neutralized by the equal stress of opposite direction; caused by the contraflexure in the columns. This is shown in fig. 4. The arrows represent the direction of the different stresses and shears; each vertical line corresponds to the flange of a column, and the horizontal lines, to the girder flanges.

Using fig. 5 as a chart, and the following notation, the stresses and shears are obtained as follows:

P = Wind loads at panel points of columns.
V = The vertical reaction of the columns.
VS = The vertical shear in the girders.
HS = The horizontal shear in the columns.
L = Distance between outside columns.
b = Breadth of knee brace (if any).
d = Depth of knee brace (if any).
c = Unsupported distance of column.
e = Unsupported distance of girders.
ϕ = Angle knee brace makes with the vertical.
n = Number of panels in the bent.

The tension in the windward column equals the compression in the leeward column, and is found by taking moments at the intersection of the floor and centre of the leeward column. Then, the sum of all the wind forces above the floor multiplied by the story height, and this divided by the distance between the outside columns equals V, or

$$V = \frac{\text{Sum. P}}{\text{L}} \text{h} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

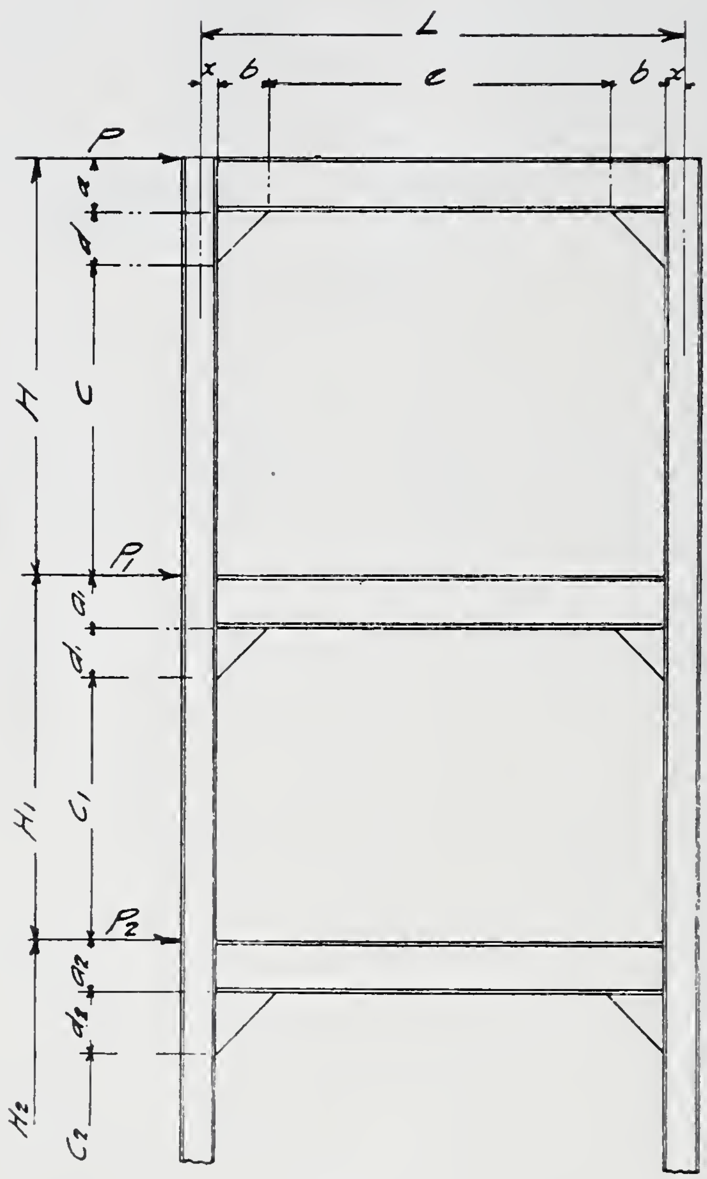


FIG. 5.

The horizontal shear in the outside columns equals the sum of all the wind forces above and including the floor in question, divided by twice the number of panels, or

$$\text{H. S.} = \frac{\text{Sum. P}}{2n} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

The horizontal shear in the interior columns equals

$$\frac{\text{Sum. P}}{n} + \frac{\text{Sum. P}}{n} \div (n-2) \quad \ldots\ldots\ldots \quad (3)$$

The vertical shear in the girders equals the sum of the wind forces above the floor, multiplied by the distance between points of contraflexure in the columns above and below the floor in question, plus the local panel wind force multiplied by the distance between the floor and point of contraflexure in the column below, and the whole expression divided by the distance from the outside column to the point of contraflexure in the girder, multiplied by the number of girders in line. Accordingly the vertical shear at the first floor down from the top, in fig 5, equals

$$\frac{\tfrac{1}{2} P\,(\tfrac{1}{2} C + a_1 + d_1 + \tfrac{1}{2} C_1) + P_1(a_1 + d_1 + \tfrac{1}{2} C_1)}{(X + b + \tfrac{1}{2} e)\, n} \qquad (4)$$

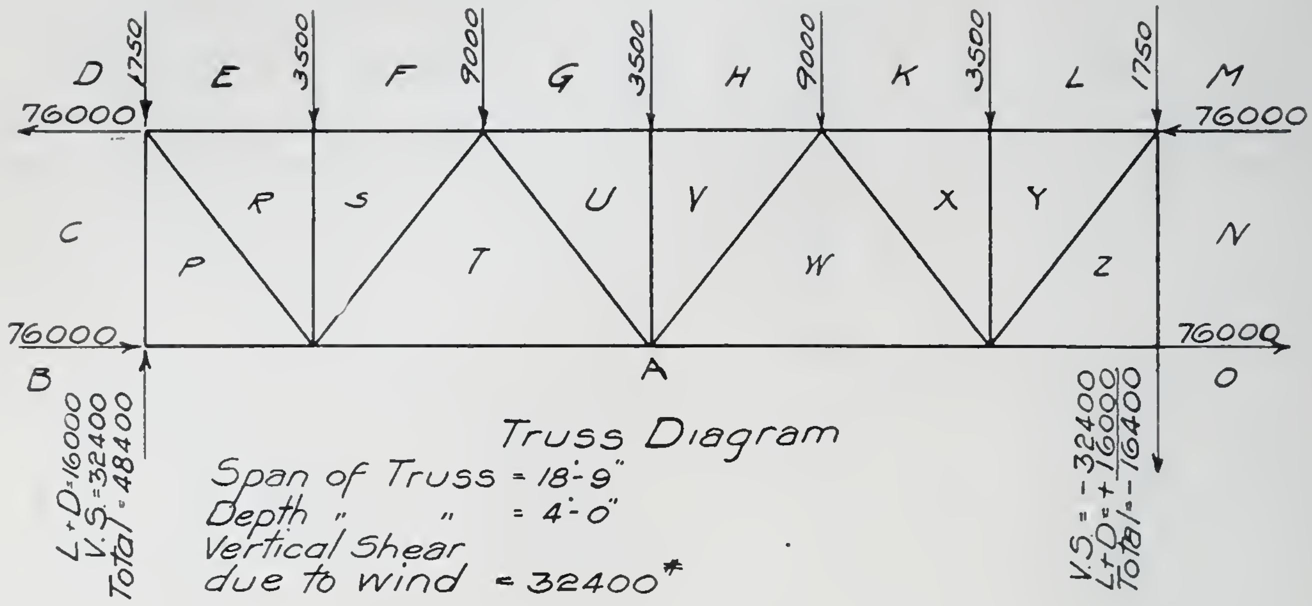
The tension or compression in the knee brace equals

$$\frac{\text{V. S. } \tfrac{1}{2}\,(e+2b)}{b} \times \text{cosecant } \phi \ \ldots\ldots\ldots (5)$$

unless exceeded by the formula

$$\frac{\text{H. S. } \tfrac{1}{2}\,(c+2d)}{d} \times \text{secant } \phi \ldots\ldots\ldots\ldots (6)$$

If in place of the beam girder and knee brace system, a lattice girder bracing be used, keeping it in the exterior walls around the frame, a much better distribution of metal will result. Here, the girders being covered by the walls, a much shallower floor is permissible than could otherwise be obtained with the knee brace; and again, the girder can be made very deep, extending from the soffit of the window below the floor to the sill of the one above, a distance usually of four to five feet and giving the shortest possible unsupported length to the columns and correspondingly small bending moments.



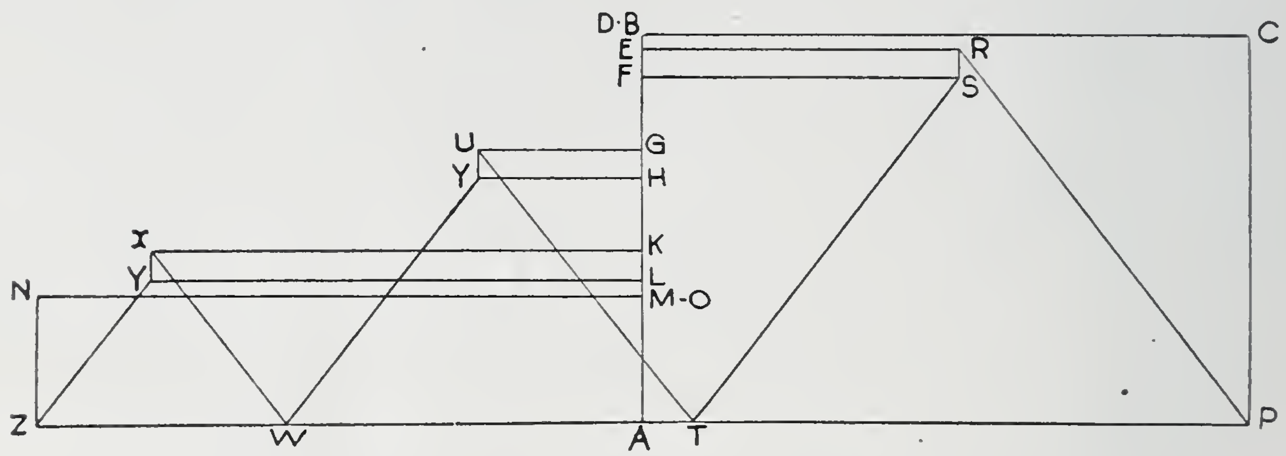


FIG. 6. Stress Diagram. The truss having a point of contraflexure mid-way between points of support, becomes a cantilever; and the point of maximum flange stress due to wind is at the point of support, and is equal to the vertical shear multiplied by one-half the span and this divided by the depth of the truss.

In the above diagram the wind is assumed to act from the left side and starting with the known forces AB and BC the joints can be analyzed in succession.

Fig. 6 is a girder of this type, being the spandrel girder at the tenth floor of a 15-story building. The vertical shear at the floor is 32 400 lbs., and this shear, combined with the live and dead load reaction, gives the maximum left hand reaction of 48 400 lbs. As the girder has fixed ends, the vertical shear will be negative for the right hand reaction, or

$$-32\ 400 + 16\ 000 = -16\ 400$$

The maximum flange stress will occur at the support, and equals $\frac{32400 \times 9.375}{4} = 76\ 000$ lbs.; the direction of the forces are shown in fig. 6, and, starting with the two known forces AB and BC, the stresses at the joints are readily analyzed.

The girder in question weighed about 70 lbs. per lineal foot, very little more than an ordinary floor girder.

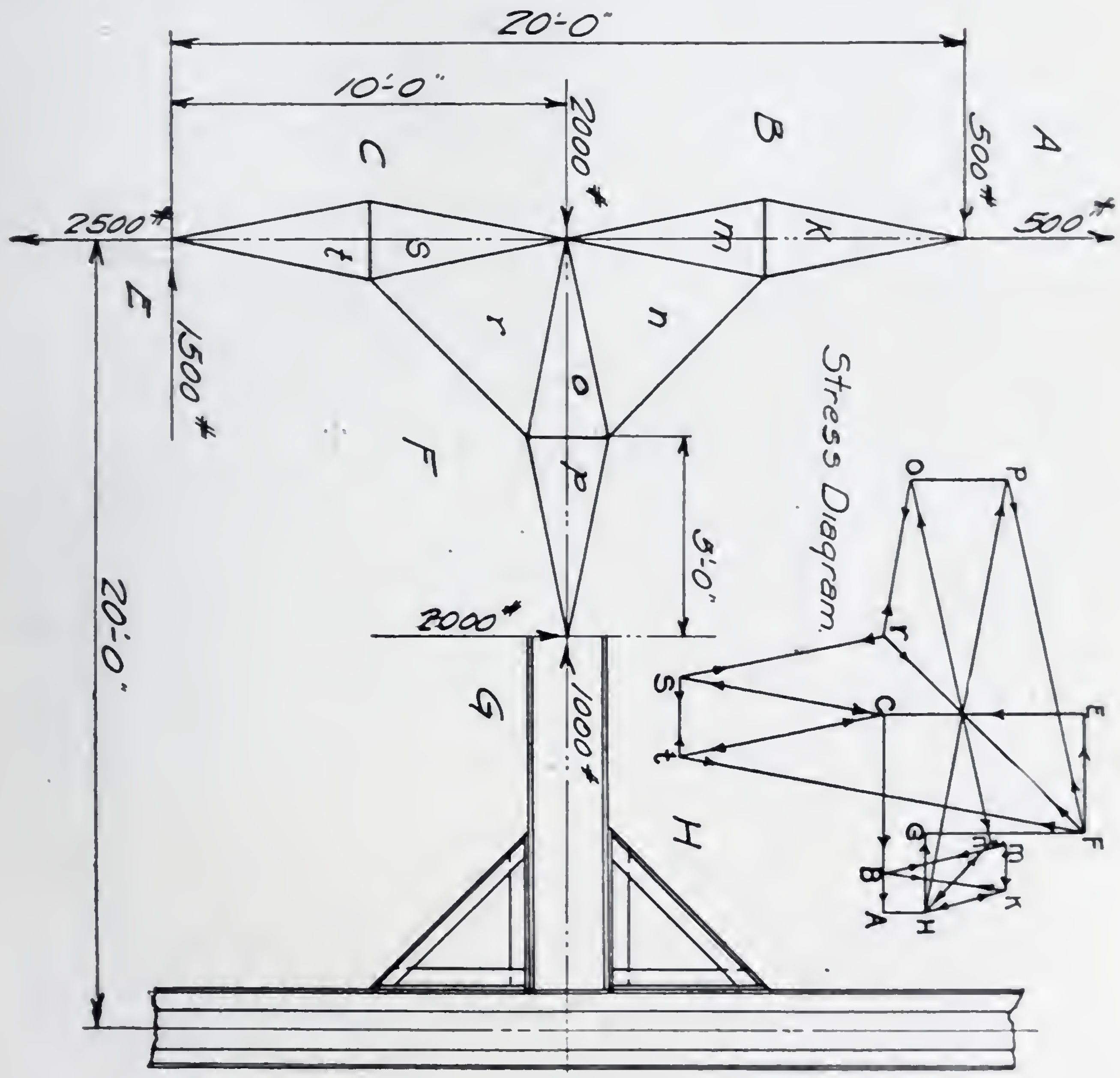


FIG. 7. Cross section through bent. Graphical analysis of tension or compression in the knee brace.

Fig. 7 is a part cross section of a two-column bent at the nth floor, showing one-half in outline; the points taken being,

the depth of girder and column, the intersection of knee brace with the girder and column, and points of contraflexure in the column and girder respectively.

The forces B-A and A-H are the horizontal and vertical reactions of the half panel load of the roof above, acting at the point of contraflecture.

The full panel load of 2000 lbs. is assumed to act at the centre of the girder.

If the distance from the point of contraflexure in the column at E, and the point of contraflexure in the column at A be 20 ft., and the horizontal shear equals 500 lbs., by taking moments at E, the vertical reaction is found to be $\frac{(500 \times 20) + (2000 \times 10)}{20} = 1500$ lbs. Added to this is the story reaction above, of 1000 lbs., or CE equals 2500 lbs.

Then by taking moments at point CHB the horizontal reaction EF is found to be 1500 lbs. The horizontal shear through the girder is the algebraic sum of the forces AB, BC and EF. Amounting to 1000 lbs.

The polygon of forces in the stress diagram would then be AB, BC, CE, EF, FG, GH, and HA.

The horizontal shear in the girder would, therefore, be due only to the local horizontal wind force, and not be accumulative, from top to bottom of the building, it could then be neglected in the design of the girder, as it will never be large enough to be a factor.

DISCUSSION.

The discussion was opened by Mr. R. B. Woodworth, who explained the theory upon which the bracing in the Farmers' Bank building was calculated. Mr. Woodworth's remarks are elaborated in the paper following the discussion, and prepared as preliminary to undertaking the design of the steel frame for that building.

Mr. J. A. McEwan: I am more interested in mill than in office buildings, and I find that while one designer

takes care of the wind stresses in a definite manner, another will allow for them only in a very general way. For example, one may assume a certain roof load per horizontal sq. ft., to include both the dead and wind loads. Another may consider the wind acting in a horizontal direction entirely independent of the vertical load. The method used is a matter of judgment and depends upon the requirements and character of the building. The columns are the principal members affected in wind bracing, and the horizontal loading, if taken into consideration, makes a great difference in the cost of building. It ought to be possible to rely upon the walls, partitions and floors to give a certain amount of stiffness to resist wind stresses, depending upon the nature of the material and method of construction, and it does not seem that the steel frame should be required to take the wind stresses in their entirety.

Mr. T. J. Wilkerson: The wind bracing of high buildings seems to me a very indefinite proposition. Of two buildings—one having an elaborate system of wind bracing and an all-steel frame, the other having cast iron columns and with the I beams of the floor system supported by lugs cast on the columns, with probably two bolts to connect the beam to the column—from all appearances the one building resists the wind as well as the other. In very high structures, such as the tower on the Singer building in New York, or even such a building as the Farmers' Bank building in this city, were they not surrounded by other buildings to protect them somewhat, it might be well to use a good system of wind bracing. In other cases I am inclined to think that the cost is not justified.

Mr. J. B. Hardie: The subject of wind bracing for high, steel framed office buildings as are now in general use, is one which impresses me as being given more or less consideration according to the opinion that may be held as to the need for special provision in the matter. In general practice of construction for this class of buildings, we find variety of methods in providing for supposed wind effects. In many cases, however, it is apparent that no other consideration has been given

wind bracing requirements, than what is afforded by the connections existing between floor beams and columns at the several floor levels, and it appeals to me that the whole fabric of such structures, when fully assembled, offers as a whole, a very high resistance to pressure from wind. In a combination such as is formed between columns, floor beams, flooring, walls, partitions, etc., there is, in my opinion, a very substantial means for resisting wind stresses.

Mr. E. W. Pittman: I recently met the contractor who is putting up the Singer tower, and he informed me that the original design for the wind bracing showed diagonal rods from one floor to the other all the way from top to bottom. The design was submitted to Purdy & Henderson for their criticism and revision, and they took out the diagonal rods and substituted knee braces at the ends of the spandrel girders all the way around; the knee braces are about six or eight feet deep.

Mr. Richard Hirsch: Following Mr. Hardie, where he states that the curtain and partition walls and the loading of the building, other than the frame proper, is of great value in bracing the building, I cannot help thinking that we should not count too much on this extra loading as wind bracing. While it is of value, yet if anything should get out of alignment, that dead weight will act as an eccentric load and tend to bring the building down.

Mr. Hardie: Much depends on the location of the structure and other conditions. Many of the high buildings of our city are so located, and so surrounded by other buildings, that the effective horizontal wind pressures may be considered as of very limited value. Circumstances may occur, however, where the conditions to be met, and the formation of the structure itself, demand that due consideration be given this problem.

Mr. Pittman: I think the knee brace at best is a very poor substitute for the diagonal system, and that the latter should be used wherever possible.

The design of a mill building was recently submitted to me which was so high that knee braces were altogether out of the question. The building was of the following dimensions: Width 76 ft., center to center of columns; length 125 ft.; bays 25 ft.; height to bottom chord 60 ft.; height to foot of knee brace 57 ft., 6 in.; height to crane rail 54 ft. Of course the shallow knee braces, 2 ft. 6 in. deep, were entirely inadequate. I redesigned the building, increasing the height of chord to 70 ft., and the depth of knee brace to 12 ft. 6 in., but it was necessary to use very deep columns to withstand the large bending moments induced by the knee braces. Fortunately it was not intended to extend the building in the future, so I finally decided to eliminate the knee braces altogether, transferring the wind loads through a system of bottom chord bracing to the end bents, and thence, through diagonal end bracing, to the foundations. This design brought the columns within reasonable limits, and proved far more economical in weight of steel.

I do not see that a side wall will take care of any wind stresses at all, but on the gable end it will serve the same purpose as diagonal rods. A curtain wall is really about the safest brace that can be devised. On buildings of indefinite length the only function that the bottom chord bracing performs is that of aligning the building and holding it in line.

Mr. Hardie: In the old section of the city of Edinburgh, Scotland, there are many high tenement dwellings of the older type, built of stone, brick, or other combinations. These buildings are from seven to twelve stories, prominently exposed to the very high wind storms that frequently visit that district, and have stood in some cases for probably a hundred years. The effect of high wind pressure on these structures is disseminated throughout the various walls, partitions and floors the same as it is in high buildings of more modern construction.

Mr. Pittman: Some time ago I read of a tall building in Chicago, the top of which, under the action of a high wind, was found to deflect three or four inches. It was found, how-

ever, that one end deflected considerably more than the other, and it developed that the diagonal bracing and knee bracing were not symmetrically disposed with reference to the center line of the building, so that a twisting as well as a direct deflection was induced in the building.

That is one point that was urged by Mr. Purdy in an article which he wrote on the subject of wind bracing—that the designer should be careful to get his system of bracing, whether of the knee or diagonal type, equally distant from the center of the building.

A THEORETICAL DISCUSSION OF THE KNEE BRACE DESIGN OF WIND BRACING IN STEEL FRAME BUILDINGS.

By R. B. Woodworth.

Stability of buildings subject to external forces is a problem to be investigated and solved in accordance with the fundamental laws of mechanics and the strength of materials as determined from the theory of flexure. Any solution of the problem which does not agree with what has been demonstrated as to the behavior of materials under stress must necessarily be imperfect, if not erroneous.

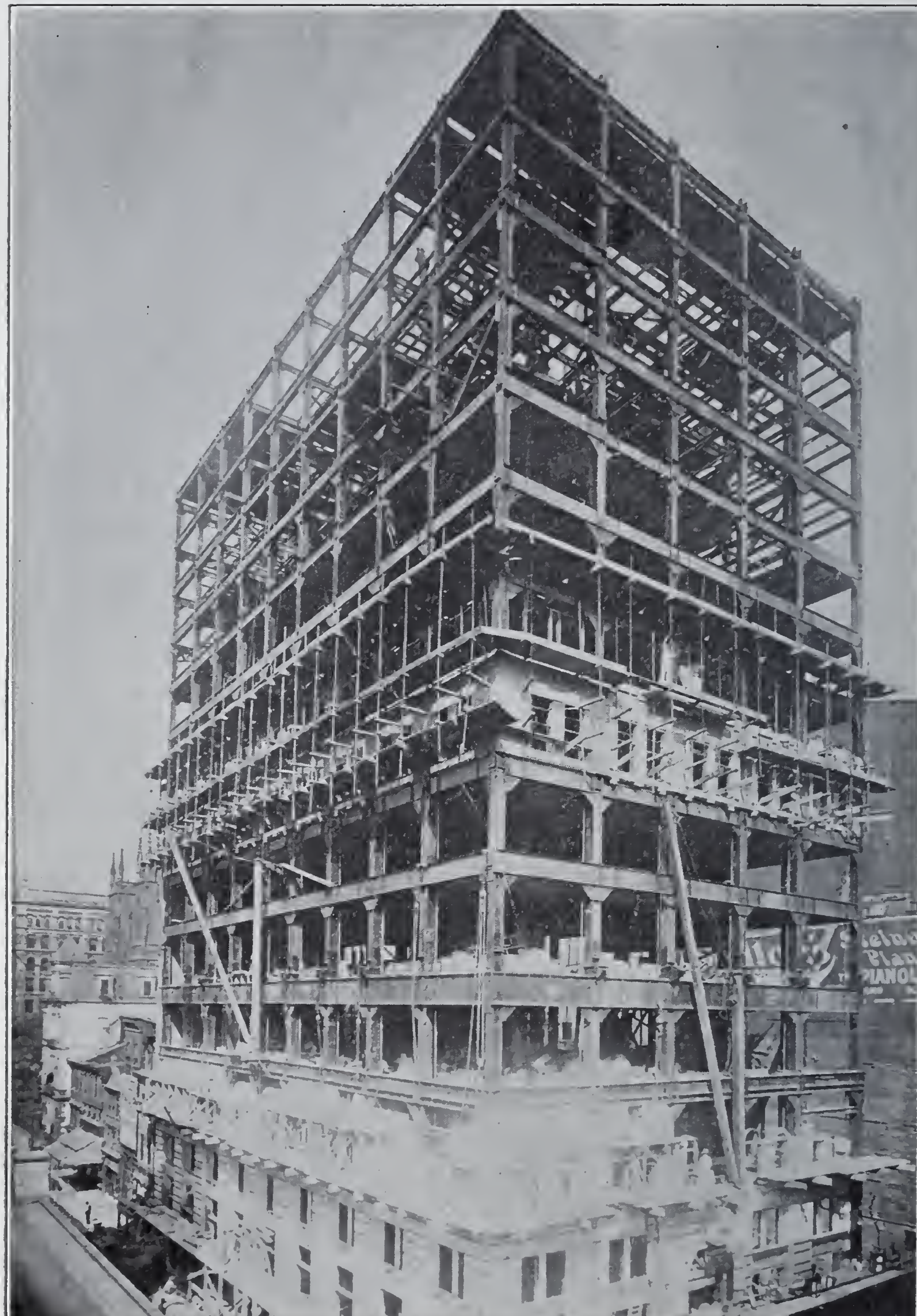
Now, a building may fail in one of three ways, in the direction either of its length or its width. It may collapse vertically by reason of the weakness of the materials of which it is composed and upon which the loads it was designed to bear are superimposed. It may give way in a horizontal direction under the influence of shearing forces, either by lateral displacement from its foundations, or by buckling of its various members on account of their weakness to resist these forces, or, if the frame work is strong enough to carry safely the vertical reactions due to the loads it may have been intended to bear, and stiff enough to resist the shearing stresses produced

by external horizontal forces, it may yet fail by being overturned bodily through its own weakness to resist the upward reactions produced by these horizontal forces.

The ordinary vertical reactions in a building caused by the loads imposed upon its frame are readily determined and provided for in its design. The external forces which cause horizontal shears that must necessarily be transformed into vertical stresses before they reach the foundations, are not so easily taken care of in its design. It is believed, however, that these also can be made amenable to satisfactory treatment and safely provided for. The only external forces acting in a horizontal direction upon a building, with rare exception, are those produced by wind and storms, and these alone produce dangerous effects, tending to overturn the building upon its base.

Now, a masonry pier is a structure subject to horizontal forces similar to those in a building caused by the pressure exerted by the wind, by the action of ice in motion, by a collision with boats, or other means. It acts as a homogeneous whole, the blocks of which it is composed resisting all compressive stresses, while the tensile stresses are taken up by the cement, drift bolts, or other means used to bind its parts firmly together into one solid mass. The moment of its resistance to all forces tending to overturn and thus destroy it is, of course, the product of its mass into half its width in the line of resultant stress. As on the already mentioned supposition —that the pier is a homogeneous whole, its neutral axis passes through its center and is distant from either side of the pier by half its width in either direction—this moment of resistance is equal to the weight of the pier multiplied by the distance from its neutral axis to the outside fibre.

A building differs from a solid masonry pier chiefly in that it is not a homogeneous whole; the vertical loads carried to its base are not uniformly distributed over the entire area of the same, nor are the members of its frame so united as to act vertically, horizontally, or diagonally with the readiness displayed in the several parts of the pier—stones, cement, dowels,



FARMERS BANK BUILDING, PITTSBURGH, PA.

The photograph was taken when the erection of the steel frame had reached the 15th floor; completed building 24 stories in height.

clamps, drift bolts, etc. And yet, when we come to consider its moment of resistance to overturning at its base, this moment can only be measured in terms of the several moments of the separate weights resting upon that base by their several and separate distances from the neutral axis. The point of application of these weights can be gotten directly from the footing plan of the building, and the position of the neutral axis, and with it the moment of resistance, determined by the usual formulas.

This neutral axis will not be coincident with the center line of the building, unless the loads are symmetrically applied on the footings. In a steel frame building this is but seldom or never the case; a heavy spandrel wall on one side and a curtain wall on the other, unequal loading due to elevator framing, stairways, vaults, and what not else—these are some of the things which make it necessary to determine the position of the neutral axis by independent calculations at each and every section made by a row of columns normal to the general direction of the axis. But when once this neutral axis is found, and the moments of these separate weights are determined, it will be at once apparent that to insure the stability of the structure it will only be necessary to proportion the several parts of the building in accordance with the laws of flexure. For, of course, the value of the building as a whole, considered as a medium of resistance to the wind, will be the value of its moment of resistance. If, now, the building is strong enough to resist all vertical reactions, and stiff enough to resist buckling under horizontal stresses, and so heavy that its moment of resistance as thus determined, will exceed the uplift on the windward side due to the overturning moment produced by the wind, there can be no question but that the structure as a whole has been correctly designed to perform all its work.

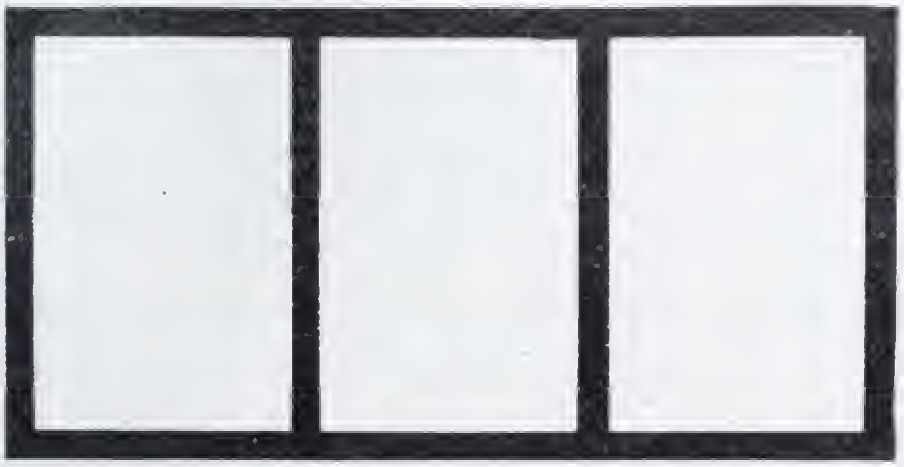
The horizontal forces by which the pressure of the wind on the sides of a building are represented, must be resisted by the internal strains in the various parts of the building, and the work to be done by the wind in overturning or buckling the

building must, in view to safety, be equaled by the work done by the parts of the structure. This consists in taking the horizontal reactions, transforming them into vertical, diagonal and horizontal stresses, and transferring them to the foundations. In this way the sides of the building must act like the chords of a truss, or the flanges of a beam, and the partitions or end walls like the web members. Now, in a building constructed with solid end walls and partitions represented in sketch No. 1, it is apparent that the building will be safe as against wind pressure only in so far as the transverse walls are strong enough to resist tension and compression caused by the transformation diagonally of horizontal shears into vertical reactions, and the side walls are strong enough to resist the crushing or pulling apart, caused by their action as chords. The materials of the interior walls, therefore, would have to be investigated as to their ability to resist shearing intensity, and the outside walls to resist compression, while the cement or other bonding material would have to be designed to resist pulling apart. If, now, the wind forces are considered as concentrated at the outside walls, and at the partitions and sections made at these points it will be readily apparent what is the true character of the building as subject to mathematical investigation.

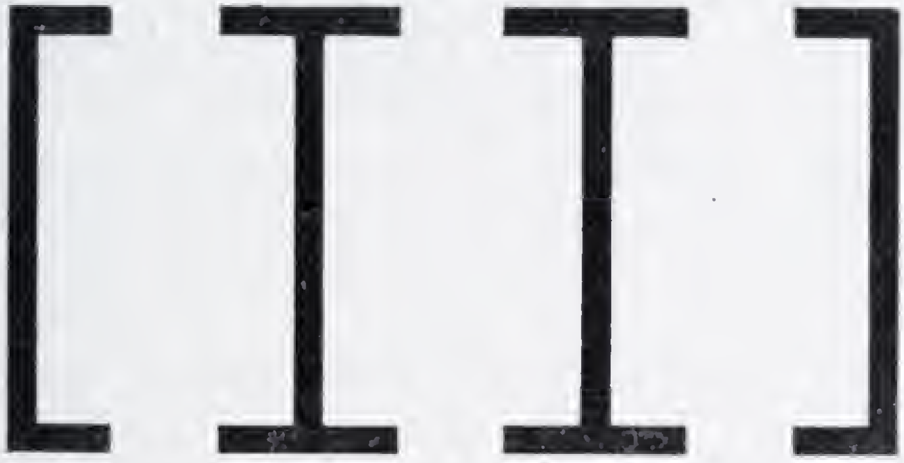
As shown by sketch No. 2, we have a series of beams and channels on end, and what is true of beams in general must be true of these stone or brick beams in particular. They must be figured as cantilever beams fixed at the foundations and loaded uniformly with the wind pressure, and the materials in them must be calculated in accordance with the usual formulas for the flexure of beams in general.

In a steel building of the skeleton type, we have no solid webs, as in the case supposed. The floors are usually open from wall to wall; the partitions are too thin to resist shearing stresses of any great intensity, and their location is never definitely and finally known to the designer, except in special portions of the building, inasmuch as they are liable to removal

at the will of the tenants. The end walls, likewise, are cut up by openings for doors and windows, and there could, in no case, exist any true bond between the materials of the wall and the steel spandrel beams or girders. Consequently, the designer cannot rely, in any measure, upon them for aid in resisting the wind forces. The stiffness of the floors, the resistance of the partitions, and the general rigidity of the building, due to care-



SKETCH NO. 1.



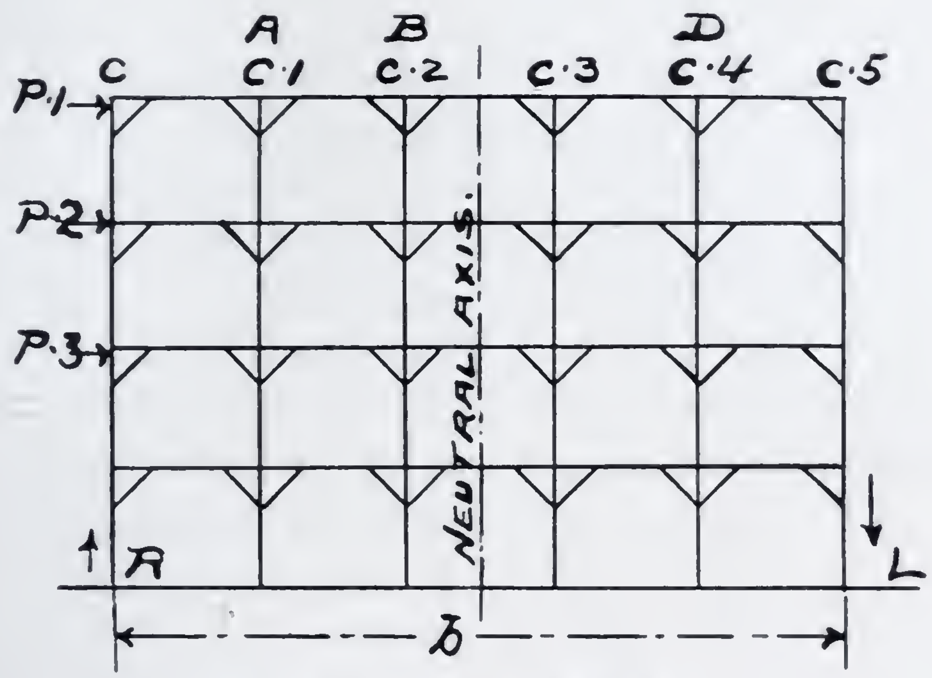
SKETCH NO. 2.

ful attention to connections, may avail much or little. It is the duty of the designer intrusted with the responsibility for the interests of the owners, and the security and perhaps the lives of the tenants, not to rely upon elements of strength, uncertain in value and irreducible to calculation. What shall he do? The answer is easy. He must make provision in his design of the steel frame to resist these horizontal forces. If

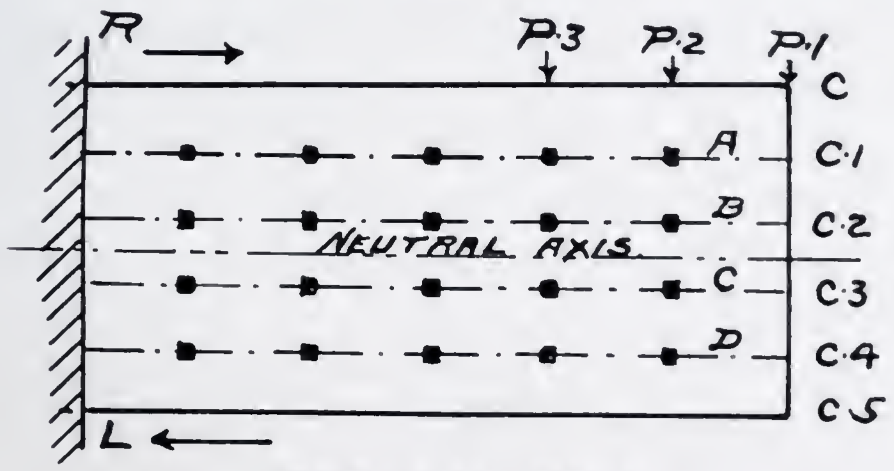
he can put in diagonal systems of wind bracing at any point, let him do so, and let him design them for the full force of the wind contributory to the area covered by their influence. If he cannot make them sufficient for the total wind force, let him make them as strong as the dead load in his columns will allow; but let him beware lest he pull up his columns bodily by the roots. If he cannot get material enough in this way to resist the figured wind pressure by such tower bracing, considering the building as a cantilever truss, with center to center of chords equal to center to center of the columns thus braced, he must do what he can further in the line of knee braces, lattice girders or portals. The calculation of a diagonal system is simple; it is believed that the method now to be outlined for bracing with plate or lattice girders and knee braces is in exact accord with the fundamental laws which must govern all calculations involved in the investigation of stability in structures.

Let a transverse section of our steel frame building be represented in sketch No. 3. It is proposed to use girders and knee braces to resist the wind forces and to transfer them into the foundation. If now the building be the same as that already discussed, with the exception that the place of the partition walls is taken by the columns, it is certain that the moment of resistance at the footings must be the same as before, lessened by the difference between the weights of the walls, etc., and the weights carried by the steel frame. The area of the base is the same, the lever arms are the same, and the only difference consists in the weights themselves and their modes of application at the footing line. The moment of resistance of the building, considered as a whole, must be computed in the same way, viz., by reference to the neutral axis. On this principle, the stresses in the outside columns must be computed as for a cantilever beam. The moments of the several wind forces about R or L will be equal to their several intensities multiplied by their distance above these points, and the stress in the outside columns (fibers of our cantilever beam) will be the quotient of their sums (total bending mo-

ment about R or L) divided by b, the depth of the beam. This stress will, of course, be tensile in the windward column, and compressive in the leeward, and equal each to the other, and will have to be added to the other stresses in the latter column caused by the vertical loads. The tensile stress in the windward column must not exceed the steady load (dead and a



SKETCH NO. 3.



SKETCH NO. 4.

small live load) on the column, otherwise anchorage must be provided to resist the upward reaction.

Let us lay our building on its side, as shown in sketch No. 4, omitting the interior columns and braces, and consider it as a cantilever beam as before. Now the forces P1, P2 and

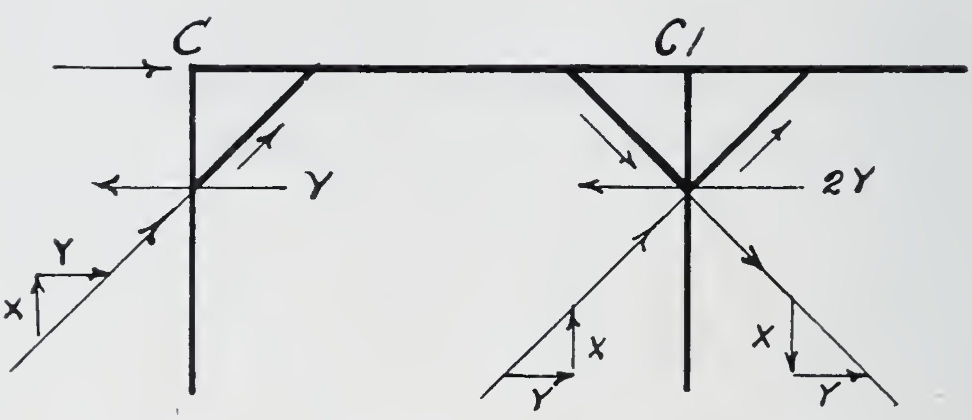
P3 produce longitudinal compressive and tensile stresses and vertical shearing stress in our beam. Take the longitudinal stresses a moment. At the top of the beam these are tensile, at the bottom they are compressive, at the neutral axis they do not exist, but at any area between the neutral exis and the top of the beam, as at A and B, or similarly between the bottom and the neutral axis, they do exist, and their intensity is directly proportional to their distance from the neutral axis. If now these areas A and B extend from end to end of the beam, the strip of beam represented by them must be subject to longitudinal stress at all points. This stress will vary in intensity parallel to the intensity of the stress in the top flange, and will always be in direct proportion thereto. By reference to sketch No. 3 it will be seen that these areas A, B, C and D, lie in the plane of column C1, C2, C3 and C4. It would appear reasonable, therefore, that if we leave out the strip of web plate between the top of the beam and A, or between A and B, as we propose to do in the use of knee braces, any columns at these planes would be stressed in proportion to their distance from this neutral axis, just exactly as they would be were the web plate entire. That is, if we leave out the solid partition walls depended upon in our primary consideration to transform horizontal shear into vertical stresses and replace them by columns and brackets, these columns and brackets must do the work supposed to be done by the walls. Moreover, were the structure to fail by deflection from the straight line, it must do so as the result of forces causing the tension flange to elongate and the compression flange to shorten as the result of the work done by them in straining the structure. It need not be said that the interior columns must follow suit, and lengthen or shorten accordingly. Any work done, therefore, by wind to induce such deflection and failure must be resisted by internal strain in these interior columns.

As to shearing effects, in a rolled beam or in a plate girder without stiffeners, the shear is constant from the top of the beam to the bottom, and its intensity per square inch is equal

to the shear at any point, divided by the area of the web plate for a strip an inch wide. The portion of the total shear taken by any section of the plate would then be equal to its depth, divided by the depth of the girder. By reference to sketch No. 4 it will be seen that if the portion of the web represented by area A be taken to include one-half of the whole strip from the line at B to the top of the beam, we can consider the whole shear in that section to be concentrated at A and acting as a unit at that point; on which consideration we have to assume that if the web is cut away, as we propose to do, then we must apply a force at A to balance this shear, otherwise our structure will fail. Now, the only stresses in our structure under present consideration are those caused by these shears in their transference from horizontal to vertical reactions. The work of this transfer is done by the brackets. The columns cannot take horizontal stresses for transmission to the foundations until the same have been transferred into vertical reactions. This transformation must be done by the brackets, and the proportion of horizontal shear taken by each bracket from the line of girders will, if our analysis be correct, be determined by the contributory area of our web plate. If our columns were spaced equally, then the outside columns would each receive one-tenth of the total shear, while the interior column would receive twice as much, or one-fifth each, strictly in proportion to the amount of web plate represented by its contributory area at any section. This also seems to result from an analysis of these brackets.

Suppose the brackets to be equally strong, then each bracket will take the same amount of shear from the girder, which now represents the thin strip of web plate and which is supposed to be equally stressed from end to end. Suppose the brackets to be cut at 45 deg. Suppose the amount of shear taken by the bracket at column C to be y (horizontal component). The bracket takes this shear by bending the girder vertically, equal to component x, and the column horizontally equal to component y. At column C1, as shown by the sketch, the bending

in the column amounts to 2y, which is as it should be on the supposition made. The interior columns then on equal spans, center to center of columns, should be calculated to resist twice the bending taken by the outside columns. The vertical stresses in the columns caused by the knee braces cannot be determined by an analysis of their reactions. For at column C1, by the analysis on sketch there would be no vertical component to go into this column, and of the total shear at this level all that would produce vertical reaction in the columns, would be one-fifth of the total, which is supposed to pass into



SKETCH No. 5.

the exterior columns. If the accumulated shear at this level were 1000 lbs., then, by analysis of the bracket, the outside columns would take 100 lbs. each as increment of chord stress, whereas, for 10 ft. story and a 10 ft. span they should take $\frac{1000 \times 10}{50} = 200$ lbs. The stresses in these brackets and bending moments in girder and columns must therefore be computed in accordance with the methods given in the standard works on portal and knee bracing in bridge construction. The vertical reactions are obtained in line with the analysis of cantilever beam work, to which allusion has already been made.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXIV JULY, 1908 No. 6

REGULAR MEETING,

June 16th, 1908.

Vice-President George T. Barnsley,

In the Chair.

TOOLS AND EQUIPMENT IN STRUCTURAL SHOPS.

By Geo. P. Thomas,*

Non-Member.

It might not be pertinent to the subject to say that neither is progress possible, nor can improvement be made without some sort of vested interest being concerned, those affected frequently raising the most strenuous objections from purely personal motives, reaching even to the smallest details of shop improvements. What enters into the make-up of a modern structural plant is largely a matter of opinion among engineers, and this difference of opinion often tends to produce neutral results. We form our opinion largely, if not altogether, by personal experience, colored more or less by the opinion and experience of others with whom we may come into contact, forming a sort of atmosphere in which we live; anything without or beyond this zone has a tendency to arouse our prejudice. A man who has long been engaged in the same kind of work, shearing, riveting or other operation, and has become highly skilled in that particular work, will usually oppose any change in method, no matter how good it may be.

*Engineer with Standard Bridge Tool Company, Pittsburgh.

Skill simply means that a man has reached the point where he can perform certain operations mechanically, and where the mind guides only in a general way. To make changes necessitates new mental efforts, hence the tendency or inclination to rebel when the mind has dropped into a groove.

A plant showing a balance at the end of the year is supposed to be successful in a way, yet that is far from being true. In the fabricating business, there are some rather primitive shops competing, even in shop cost, with some of the best equipped plants. By analyzing the conditions in such establishments, the reason can readily be discovered; the shortcoming of the equipment is made up by the higher efficiency in management and men, a condition rather hard to obtain under our present industrial conditions. In any manufacturing establishment, there are three elements: Management, workmen and equipment, and any deficiency in one must, in a way, be made up by the others. There is a certain balance between them which must be maintained to obtain satisfactory results.

Another type of shop which, with limited facilities, enters this apparently successful competition, is the long established concern, with men who have been in its service for years, and where any change or improvement in method is frowned upon and where very little new blood is ever introduced. The organization is of the simplest, fixed expenses are low, and the efficiency of the men is high. Such conditions in a shop would be ideal if they did not entail slow but sure extinction in the end; such shops get deeper and deeper in the rut which finally buries them; for years they keep on extracting the vitality of the concern and put nothing in. The company constantly striving for betterment necessarily has higher fixed charges, the up-keep of the plant is more and the depreciation greater; yet if, at the end of the year, it shows no greater money return than the shop cited above, its management has been a success for, instead of losing vitality, it has increased it. This, coupled with the better and superior class of work made possible by the better equipment, ought to prove entirely satisfy-

ing to the owners. Improvements should be made gradually; too much new blood and too many rapid changes mean disorganization and friction, and may double the cost of improvements.

Fabricating plants have peculiarities all their own. The problem here involved is one largely of handling and applies, not only in carrying material about for the various operations, but the actual operations as well. Positioning a piece in a shear or punch, or for riveting, takes greater time than the actual performance of the work. The efforts to reduce costs in machine shops are made largely by aiming to reduce the time of operations by improved and more powerful tools, by increasing cutting speeds, and by using high speed steel, jigs and other time-saving appliances. In fabricating shops the aim has been almost exclusively to lessen the time to position the material for the required operation and for removing it. In a modern shop this is in evidence everywhere; in the arrangement of overhead cranes, skids, punches, reaming gantries, and special cranes for handling riveters. In laying out a plant and taking into consideration all the various details, it is very easy to go astray. The shop must be laid out to work almost as a unit, and consequently all the various operations must be well balanced and properly located in relation to each other to work on an economical basis. The idea of building a structural plant on a scale for taking care of future growth and equipped only for the present, sounds well in theory, but is not so easy to carry out in practice if efficiency is an object to be obtained. A machine shop or foundry may be added to, from time to time, without destroying the general scheme; but this is almost impossible in a fabricating plant and at the same time keep it properly arranged and not disturb the equipment already installed. In a progressive shop the continual growth and the gradual changes in the management, men and methods, make the laying-down of a shop scheme, to be carried out in the distant future, an altogether uncertain quantity, and is seldom completed as originally planned. Better results are obtained by equipping for the present, allowing the future to

care for itself. Providing equipment for extremes is also wrong; for instance, to provide a 10-ton crane where 95 per cent. of the lifts will not exceed 2000 lbs., as in the marking, shearing and punching area. Cranes of ample capacity should be provided, but far better results are obtained by installing cranes adapted for the lighter lifts and dividing the loads for the heavier ones. This applies also to machine capacity.

The aim in a modern plant is to keep the material always moving forward from one operation to the next. Return movements will occur, but they should be the exception and not the rule. As previously stated, to obtain the highest efficiency the shop must work as a unit, and makes location of sections in relation to each other important. Local conditions usually affect the shop plans more or less, but the best conditions are obtained when the storage yard can be located at the entering end of the shop and the loading yard at the finishing end, with narrow gauge tracks connecting the two. Some shops have tracks running into the shop from the storage yard on a slight down grade, permitting loaded cars to run into the shop by gravity. If, from the arrangement of the plant, an outlet for material must be provided through the storage yard, a parallel level track can be provided.

The first group of operations in the shop are marking, shearing, punching and storing. The storage space for punched material practically makes a division. Beyond the storage space the assembling, reaming, riveting, finishing and other necessary operations are suitably located. To keep track of material as it is received, the storage yard is usually divided into numbered sections. The foreman receives material sheets for each contract with blank spaces for date when received, number of yard section in which material is stored, and date when finally delivered to the shop. In the best shops the marking and shearing operations are placed together. Material brought in on a narrow gauge car from the yard is handled by overhead cranes and placed on storage skids, which should be provided throughout the shop, and nothing should be placed on the floor except such pieces as can be handled with-

out a crane. Skids for storage should be from 10 to 12 in. high; for marking, about 28 to 30 in.; for punches, usually the same height as the die, about 28 to 30 in.; for assembling, 20 to 24 in. For serving shears a combination of rollers and skids is used in many shops. Skids facilitate the handling of material throughout in bulk, as well as in detail, and to keep the shop in an orderly appearance they should be anchored down tight.

A book could be written on the subject of punching. Many shops simply range their machines along the wall and provide overhead slings to feed them, with a travelling crane covering the whole floor space to bring material and carry it away. With this arrangement the most valuable part of the shop is not utilized except for storage of material. In some cases punches are located in the center of the shop, roll-tables being used instead of slings; but if many machines are to be served, the overhead crane cannot possibly keep them going. Another system adopted by some of the leading shops, is to run special cranes transversely to serve all tools as well as punches, and permits a better arrangement of tools and saves space. It does not, however, provide any means for transferring material forward, and for doing this, narrow gauge cars must be used. Carrying material in bulk in the punch shop or providing means for carrying stuff from one end of the shop to the other is not so much desired as the prompt serving of tools, and in a properly arranged shop such movement of material should be a rare exception.

To get the best results from each punch, they should be specialized as much as possible, keeping each machine on one class of work as much as conditions will permit. The serving of punches is receiving more and more attention. The feeding apparatus is of as much, if not of more importance than the punch itself. Roll-tables used with a punch equipped with a gag, and controlling the material with a hand lever, give excellent results, and are a step in advance of the overhead sling and trolley besides permitting a more suitable crane system to be installed and a better arrangement of machines on the floor.

The ideal way of punching material is with a spacing table, a suitable machine of this kind eliminating many difficulties and is one of the most important tools in the shop. It reduces the templet making, eliminates marking, does better punching and more of it at less cost on account of the regular spacing of holes, and effects considerable saving in assembling and reaming.

Punching has many mysteries of its own, the behavior of the material being the source of much trouble, and the curving of angles particularly troublesome. Straightening is not only a slow and tedious job, but stretches and strains the piece, changes the spacing of holes, gives trouble in assembling, necessitates reaming and affects the elastic limit of the material to some extent. In designing, attention is seldom given to this treatment of the material; it is considered a sort of unavoidable evil necessary in fabricating. Plates also stretch in punching, particularly thick and narrow cover or universal plates, the stretching varying with every plate or shape. There are several causes for this trouble aside from the mere thickness of the metal. In rolling, the heavier sections retain the heat longer and are finished at a higher temperature than the thinner ones, resulting in a lower elastic limit and leaving the metal softer and with a greater tendency to stretch in punching. Pieces having the same section will also show variations due, more or less, to rolling at various temperatures. The shape of the punch also has some bearing on this. Many shops use punches with slightly convex ends to strengthen the cutting edge, thereby greatly increasing their life. This shape creates a slight tendency to drift the material away from the cutting edge and to stretch the material all around the hole; but such punches are very hard to strip unless well greased.

Some years ago I made some experiments to determine how much the shape of the punches affected the stretch of material, and I found that convex ends increased the stretch very materially and was still further increased by the shape and the size of the centering tip. Flat punches were much better and made a cleaner hole, while punches with a slightly

concave point punched a hole almost as clean as a drilled hole, and freed themselves without a stripper. In punching thick angles with such punches the curving is not entirely eliminated, but is greatly reduced. They are not practical however for general use, the edges breaking off rapidly after punching several hundred holes, where 2000 to 4000 holes are obtained with standard punches. On a spacing table the tendency to stretch can be reduced by using flat punches made with a slight clearance and without a tip; a clean-cut hole is produced and strips easily. The elastic limit and the degree of hardness of ordinary open hearth steel vary greatly, and every shop superintendent knows that no two pieces are ever found alike, varying from extreme softness to a glass-like hardness, in some cases flying to pieces in punching, or cracking all around the hole. In punching thin plates or shapes, which are very apt to be hard from rolling at low heat, the hardness is indicated by the loud report made by the punch in going through the material.

Next to the punching, comes the storage for punched material. The importance of providing ample storage space for punched material other than details, is not appreciated in many shops. The details should be sheared, punched and stored with a view of avoiding the necessity of carrying them about. Many managers prefer to segregate this part of the work in a small building by itself. In my opinion, this is not necessary as the storing of the details should be located not far from the assemblers or as close to them as possible. This storage space can, like the storage yard, be divided into numbered sections, and material delivered there can be easily located; the foreman in charge of the punch shop can trace it from the time it is received from the storage yard, until it passes out of his hands into the storage space ready for the assemblers. Low-level skids about 8 in. to 10 in. high should be provided for the shapes and narrow plates. Wide plates should be stored on edge rather than flat-wise, as the plates on the bottom of a pile are usually wanted first. Then again, there are several other advantages, space is saved, plates are not so apt

to be bent in handling, and they can be picked up by crane more easily. A good means of storage can be had by providing strong posts placed in rows with about 18 in. spaces, and from three to four feet apart, the height being governed by the width of the plates. For handling, a yoke fitted with a pin, is slipped over the plate at its center, the pin engaging one of the edge holes, the yoke being left on the plate until it is delivered to the assemblers. Plates stored in this manner can be shuffled like the leaves of a book and any one may be picked out without disturbing the others.

The assembling should be close to the storage space. Good strong skids 24 in. high, topped with about 70 lb. rails and spaced about six feet apart make a very good arrangement. They provide a level space for the assembling of material and avoid the danger connected with the use of wooden horses which are in every way unsatisfactory. In some shops a space on the floor is provided for assembling large girders. Plates provided with T slots are located about 10 or 12 ft. apart, resting on concrete piers and all carefully leveled. In this way the assembling of girders is greatly simplified, any desired camber being quickly obtained by blocking up the bottom chord. The arrangement for reaming and riveting is largely affected by the system of crane adopted; reaming and riveting gantries permitting better use of the floor space and allowing a better arrangement and division of the tools. An overhead trolley is just as good to handle a riveter, but when located in the middle of the floor it interferes with the overhead cranes and it is impossible, unless the shop be pushed to extreme lengths, to get sufficient wall space to locate all operations along the wall. It is not a question as to whether a gantry or overhead crane is the better system of handling or serving riveters, but simply, "Which will use all available floor space to the best advantage?" Riveting, like punching, has many problems—crane system, riveters, furnaces—matters on which no two engineers or shop managers can agree.

The end to attain, of course, is to drive tight rivets at as low a cost as possible. Much of the trouble with loose rivets

is caused by the carbonizing and scaling of the commonly used soft steel rivet in gas furnaces. In the Pittsburgh district many firms make their own rivets, heating the bars in a natural gas furnace and incidentally soaking in carbon and making a hard steel skin varying in thickness according to the time exposed. Again, this process is continued when heating rivets for driving, being allowed to soak in the furnace sometimes for hours before being used, the amount of carbon absorbed being so great that the rivets are practically hard steel. Carbonized rivets, even if highly heated, are very hard to drive; the metal does not flow in upsetting, the button sets are quickly worn and the wear on the riveter is greatly increased. In driving the rivets the metal is upset first where the pressure is directly applied. As one head of the rivet is already formed and the die fits this head snugly, the upsetting first begins at the extreme end, gradually forming the head as the riveter closes, the upsetting of the body to fill the hole being last. This is the principal difficulty, the body is the last to receive the pressure while it is the first to begin to cool from coming into contact with the plates. Combining this tendency to cool rapidly in the hole, with rivets having a hard steel surface from absorbing carbon in heating, more or less trouble can hardly be avoided. To avoid carbonizing altogether, involves problems in furnace construction; the rivets should not be allowed to come into contact with the flames. To remove the scale is also a factor to consider, and I believe it would pay to pickle the rivets, the cost incurred being saved in the repairs of the upsetting dies.

Structural material costs about two and one-half or three times as much as the fabrication. If a modern plant does not reduce the cost of fabricating, it will produce a better class of work which will permit a higher factor of safety to be used, and as a direct result a saving in material is made possible. This is of greater consideration than the mere reducing of fabricating cost.

While material should be punched so as to decrease stretching and overcome initial strains, the holes so spaced

that they match, and due care taken in riveting, an increased factor of safety should be allowed where the material is stretched and strained in punching and straightening, drifted in assembling, and poorly riveted. In former days almost any kind of work was permitted in boiler construction, the sheets being strained in punching, and pulled and stretched by drifting where holes did not match. The result was that, although there was plenty of metal used, the boilers were weak. Boiler explosions, many of them disastrous, made better workmanship a necessity, and care is now taken to avoid initial strains, drifting is not allowed and the riveting is carefully done. Stronger and safer boilers are built, not so much from the increase in weight of the material used, as from superior workmanship, and I believe this is worthy of consideration in the fabricating shop.

The first cost of tools is not so much a consideration as what the cost of maintenance will be in proportion to results obtained. Into this also enters the personal element that is to run the shop. The study of social questions in connection with the engineering of the plant usually receives some consideration, but it should receive far more than it does. Careless and inefficient management fosters that indifferent spirit so much in evidence in some shops. The direct fruit of this is low efficiency per man, inferior work, abuse of tools and machinery and waste of supplies. There is no doubt but that a careful and considerate management, while it will not entirely eliminate this, will greatly reduce it. There is a disposition to treat abuse of machinery and general lack of interest in workmen as an evidence of limited intelligence. To a certain extent, this may be true, but I believe that shop conditions also have considerable to do with it. In many shops, to increase the output and at the same time let the men share the benefit with the company, the premium plan is used, and has been found satisfactory wherever it has been given a fair trial. It means a little more bookkeeping but it is certainly worth many times the extra expense. Besides giving industrious men an incentive to work, it gives exact records of cost. To know

the cost of every operation in a plant, and have means to keep close watch on it at all times, is a valuable asset. To introduce this system requires patience and time, and as conditions and equipment vary in every plant, the system must be modified to suit. It should be introduced gradually, but before trying it at all, records should be made and tabulated for a certain period, the longer the better, and in any event, for not less than three or four months.

Some of our philosophers have made the assertion that progress is but relative. This applies with force to the shop. A plant is never complete unless it has reached the turning point in its career, and the solving of one problem only brings others to solve.

I have probably wandered from the subject, in speaking on the status of shop management and social questions; engineers usually are not supposed to be authorities in such matters. I venture to say, however, that a shop, no matter how well equipped and arranged, depends for success just as much on the solution of social problems as engineering ones, and that failure to get results is frequently put on the engineer and shortcoming of the equipment, when it is the personal element that is at fault.

DISCUSSION.

Vice-President Barnsley: Gentlemen, Mr. Thomas has presented us a paper upon a most important subject and has given us much information upon many points in structural shop equipment. The subject is now open for general discussion, and I am going to ask Mr. Prichard to talk to us.

Mr. Henry S. Prichard: Occasionally an engineer connected with a structural steel business may have the responsibility of making radical changes in a structural shop; at times he may even have the rare privilege of designing and equipping a shop entirely to his liking, but he always has the opportunity of contributing toward the efficiency of the shop by acquiring a thorough knowledge of it, and adapting himself to its economies and capabilities in matters which touch

his particular connection with the business, whether it be general management, sales, designing, draughting, accounting for costs, arranging piece-work systems, or direct shop superintendence.

As an illustration of the need of a broad understanding of shop economy when taking contracts, a case may be cited where a rush order was accepted for forty or fifty railroad signal bridges, each of which consisted of a shop-riveted light frame-work some fifty feet long by 5 ft. wide and 8 ft. high, or thereabouts. By the time a considerable number were assembled there was no doubt that the shop was full of work, in fact so full of light work which, as the foreman put it, did not amount to anything, that it seriously interfered with the fabrication of other and really desirable product.

When an opportunity for making improvements occurs, the commercial aspect should be the paramount consideration; in other words, the making and extent of the improvement should depend on a proper answer to the questions, "How much expenditure, with due regard to other financial demands, can be afforded?" and "If the money be expended, will it bring an adequate increase in revenue?" It is not always the one who excels in engineering and mechanical knowledge who is best able to decide the commercial aspects of the question.

In questions of structural shop economy a comprehensive view is essential to wise decision. The cost and quality of each operation of the construction, from design to erection, is, to a large extent, contingent upon the accuracy, rapidity and system with which the previous operations have been performed. The economy of each operation should be gaged by its ultimate results and not by its immediate cost.

A very important part of the equipment of every business is the character and training of the men who run it—from the manager to the humblest laborer—and the organization by which they are knit together. In the structural business especially, earnest, able leaders, fine organization and an enthusi-

astic well drilled force imbued with a feeling of common fellowship and determined to make the most of their opportunities, can overcome a very considerable handicap in the way of inferior mechanical equipment, in competing with those who are less efficient.

The interesting paper of the evening and its discussion, in addition to outlining much that is commonly accepted by those who speak with authority, has brought up a number of open questions. What is the best arrangement of cranes? For a while it seemed to be a question between longitudinal and transverse travel but one of the newest of the large bridge shops is equipped with jib cranes. What is the best floor for a structural shop? What are the relative merits of coke and gas heating furnaces for rivets? These are some of the questions the speaker would like to hear discussed by those in direct charge of, or by those who come into intimate contact with structural shops and methods.

Mr. Richard Hirsch: One thing that appeals to me is where Mr. Thomas spoke of the old-time shop where they had none of the modern labor-saving appliances. I cannot help but think that this opens up a matter that, in itself, might be the subject of a paper—"Shop Management." I have in mind a shop that came under that class a number of years ago. It was an old establishment that had grown gradually from the time of its organization, and without much method in its growth. They came to a point where they did a big business with but very meagre equipment. There was not a power crane in the shop, and their tools were all old. They did a large and profitable business, and all on account of the shop organization, which from the general manager down to the very last man in the shop, were men of long service with the company; this, together with small investment, low fixed charges and rigidly economical management, counter-balanced the handicap of poor equipment. In later years, the concern passed into a new management, and with a new organization, with heavy investment in tools, appliances and buildings, while no doubt there was a good return on all money expended,

nevertheless the old concern operated on a good paying basis for years.

On the other hand, it is quite possible for an organization to be built up to such an extent, with such heavy over-head expense, and with so much unproductive officialdom, as to seriously affect the company's ability to do business in an open competitive market, and a single department in an organization may be so over-systematized as to impair its usefulness.

Chairman Barnsley: There is another side to this question. Many of our engineers, while they do not have to do strictly with structural shop equipment, have a very great interest in what the structural shop can turn out and how quickly they can do it, especially when in a great hurry for an order. I am going to ask Mr. Wilkerson to speak on the subject.

Mr. T. J. Wilkerson: My practical experience is not very extensive on shop equipment or shop practice in detail. I have observed, however, that the shop cost on small urgent orders appeared high and, upon investigation, found it was due to the work not following the routine through the shop, causing some units to be idle. As the author of the paper has said, it is necessary to keep all units of the shop in operation all the time to obtain the best results financially, and on small urgent orders this is almost impossible.

Mr. G. H. Danforth: I would like to ask Mr. Thomas if the reference he makes to shops with the cross-travel cranes, means that he considers them better than shops having cranes with longitudinal travel, and also what he thinks of open hearth steel punches and dies, as compared with crucible steel?

Mr. Thomas: I believe that a transverse system of cranes is better for the reasons I have already mentioned in the paper. Besides allowing a better arrangement of tools and machinery on the floor and saving floor space, this system allows a more suitable type of crane to be installed. The new plant of the American Bridge Co., at Ambridge, is built on this plan; also the plant of the McClintic-Marshall Co., at Rankin. The shop can be made quite wide and divided into sections for the different successive operations. With cranes running longitu-

dinally no division is possible, operations must be stretched along to undue length and a much more expensive type of crane must be installed.

Many people get very good results from the use of open hearth steel, not only for punches, but for all kinds of tools, such as punch dies, rivet dies, etc. The results obtained are not quite as good as with crucible steel as the quality is not so uniform, but if the proper carbon is used for the different tools, the results will very nearly equal those obtained with crucible steel. An open hearth steel punch will average about 2500 or 3000 holes, according to the thickness of the material punched; a crucible steel punch possibly 10 per cent. more.

For heating rivets, I prefer coke fires for the reasons already mentioned. Carbonizing and scaling of rivets in a gas furnace is an evil that causes a great deal of trouble. Natural gas is nothing more than hydro-carbon, and steel at red heat coming into contact with the hot gases or flames of hydro-carbon will absorb carbon varying in depth according to the time exposed.

Mr. G. E. Flanagan: I think it is a good thing to lay stress on the necessity of system in taking work through the shop. To begin with, it is a good idea to follow a systematic plan in making the drawings, adhering as closely as possible to a fixed arrangement of views and manner of drawing, a regular standard of sizes, and even a standard form of lettering. The basis of the system of drawing should be to show everything in the clearest and most unmistakable manner throughout.

I think if I had been asked the question a few years ago, "What is one of the most important things to be considered in the construction of a shop, either for structural or general machine purposes?" I would have laid great stress on the necessity of plenty of natural light. It seems less necessary to insist upon that now, in view of some of the more recent structures, but there are still a few who do not seem to value the daylight. They do not seem to realize the full value of light of any kind, nor the immense advantage possessed by a shop

that is furnished with an abundance of light, and which affects both the quantity and quality of product. One of the speakers of the evening, Mr. Hirsch, referred to the shop that is overburdened with organization. That is another thing that does happen sometimes. We are very apt to make a hobby of a system and carry it a great deal further than necessary. The principal thing for a management to do is to make a thorough study of a proposed system, looking well into its bearing on the particular work to be done and the possibilities of growth of the establishment in question. System should not be worshipped as an idol. Each case should be studied thoroughly, and just so much system introduced as will be beneficial. The system suitable to the big shop should not be put into the little one.

Mr. Charles A. Norton: In view of what Mr. Hirsch said about concerns that are almost entirely without equipment whatever, competing with larger establishments—one shop I know of made a number of heavy girders weighing ten tons each, the only tool being a single punch, all the rivets were driven by hand, and still the cost was kept down to quite a low figure.

Mr. Paul S. Whitman: I am inclined to think that the personal equation, in the matter of getting out tonnage, is the main matter at issue. The president of a shop out in Indianapolis told me, on good authority, that they got out 13 tons per man per month. I am sure there are a number of Pittsburgh shops that are equipped with the very latest machinery, the very best cranes and have every possible improvement, that cannot nearly reach the output of this shop, which had nothing but overhead hand cranes.

Mr. C. B. Albree: I think the tonnage depends so much on the character of the work that one can hardly determine upon a tonnage rate per man which would be a fair ratio. One point has been brought out which, it seems to me, has as much bearing on the output of the shop as anything else, and that is in the purchasing agent and the management—to have the material on hand, ready to go ahead with the work, and not

to go on with a job and then find that certain material has not been ordered, or the patterns have not come, or something of that sort, necessitating that the whole thing be laid aside. I think there is as much loss that way as in any other, and especially is that true on rush jobs, which, for that reason, are very often unprofitable.

Mr. Flanagan: Some stress has been laid on the possibility of turning out work cheaply in the small shop. That is doubtless true, and in many cases it can be done as well as in the better equipped one, but they leave out of sight the fact that the small shop is not of much use when the hurry order comes in. Such shops have no facilities to handle material, and can only work at the customary gait. In any case, it is not an ideal thing for the management to consider only the question of whether or not they can do work cheaply at the present time. They ought to know if there is not a better way of doing those things which will lead to valuable results in the future. It is rather a short sighted management that shuts its eyes to the possibilities of good from the many improvements which are offered, and simply refuses them because it can be figured out that with a system of very strict economy and by watching the pennies, work can be done, for the time being, just as cheaply, or even at slightly less cost. Those shops will not develop. The progressive ones are those which are constantly looking for better methods, as well as those just as cheap.

Mr. J. H. Thompson: The equipment of shops is a pretty broad question. A manager may have ideas by which he can facilitate and cheapen the work, but those higher in authority may not agree with him and will not invest the necessary money.

Mr. Thomas referred to punches made of open hearth steel. That is a matter which has been gone into quite extensively and valuable records have been obtained. On the same character of work and with the same machines, the number of holes made with one punch ranged from 1500, with the use of open hearth steel, to 15 000 with crucible steel. A certain

new brand of steel recently introduced and used for making rivet dies, requiring neither annealing nor tempering, has a record of from 8000 to 33 000 rivets driven without returning the die. A die of ordinary tempered crucible steel will drive from 2500 to 4000 rivets, depending upon the character of the machine.

Mr. Thomas: This matter of steel, just referred to by Mr. Thompson, is a subject of study in nearly every shop. Some are using open hearth steel for many tools, in place of crucible, with very good results. The carbon to use for different tools, however, must be determined. A great many of the troubles with rivet dies are not, in my opinion, entirely due to the quality of steel used. I believe the chief source of trouble is in the making and heating of the rivets. The physical treatment of structural material is bound to receive more attention in the future and the variations in quality will probably receive as much attention as the production of steel rails is now receiving. This variation in steel must be taken into account, and on important structures the designer must provide for the uncertainties of the material.

Before the Mechanical Section, June 2, 1908.

Chairman G. E. Flanagan

Presiding.

AUTOMATIC FIRE PROTECTION.

By W. A. Neracher,*

Non-Member.

This is a most important topic. In fact, hardly anything within the realm of public economics could be more so, when we think of the hundreds and thousands of lives annually destroyed by fires and from panics resulting therefrom. The absolute destruction of wealth through fires now averages $251 000 000 yearly, which represents 46 per cent. of the net earnings of the Nation's railways, is 32 per cent. more than their annual dividends, exceeds, by 68 per cent., the annual liabilities from commercial failure, and is over seven times the interest on the National debt. The important point for us to remember is that no matter how much insurance may be carried on this destroyed property, the entire burden of this enormous loss is ultimately imposed upon all of us, for fire losses are actual, and not nominal or speculative in their nature. While fire insurance companies seemingly pay these losses, they actually do nothing more than distribute them among many persons, and we have not only business, but public economic reasons for taking every possible precaution against the occurrence and spread of fire.

Every citizen of influence owes a duty to the commonwealth in seeing to it that needless fire waste is eliminated or reduced to a minimum, for fires of almost every nature are amenable to automatic control. It has been aptly said that the time to put out a fire is when it starts, and this is exactly what the automatic sprinkler does. When the heat in any part of a building reaches 155 deg. fahr., the automatic sprinkler opens, checking and extinguishing the fire just where it starts.

The history of automatic fire extinguishment seems to

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date back into the 17th century. According to Woodbury, the wooden floors of a building are generally of sufficient caloric value as fuel to evaporate, by their combustion, a quantity of water equivalent to the depth of two or three feet over the floor area, and it is therefore not surprising that this great amount of fuel should have attracted attention as a source of energy which might, in turn, be used for the automatic extinguishment of fire. It is recorded that, as early as the year 1723, a man named Godfrey conceived an automatic fire extinguisher system, comprising a cask containing an extinguishing solution, the cask having a pewter chamber filled with gun-powder and connected to a system of fuses. It appears that this system was installed in a 3-story building in London, was officially tested and declared successful.

In the year 1806 John Carey patented an automatic fire extinguisher system consisting of open sprinkler heads attached to pipes which were connected to an elevated water tank. Normally the pipes were empty, the water being turned into them in case of fire by weighted valves which were allowed to open by the burning of combustible cords.

In the year 1812, Sir William Cosgrove patented an automatic fire sprinkler in which the valve or nozzle was kept closed by a cement said to fuse at 110 deg., his patent specifications explaining the functions of his automatic sprinkler to be: "An apparatus for extinguishing fires which shall be brought to bear upon the precise part where the flames exist," this being a concise description comprising about all that can be said of the state of the art as it exists today, but while the idea was good, his apparatus fell far short of solving the important problem of automatic fire control.

The next important step in the development of the automatic sprinkler system was made by Major A. Stewart Harrison. The water deflector or distributor of his sprinkler was perforated something like the top of a pepper box, and while this proved defective, the sprinkler head had a valve plug which was held in place by fusible solder, and was probably the best and most practical device made up to that date. The low

fusible alloys generally used in the automatic fire sprinklers of our present day, were first made by Sir Isaac Newton, master of the mint, in the year 1699. He discovered the important fact that certain alloys possessed lower melting points than any of their constituents The solder now generally used for automatic sprinklers consists of four parts bismuth, two parts lead, one part tin and one part cadmium, this formula being based on U. S. letters patent granted to Barnabas Wood, of Nashville, Tenn., on March 20, 1860. Perforated pipes, having holes filled with fusible solder also played a preliminary part in the development of the present sprinkler pipe system, but these soon gave way to solid lines of piping provided with fittings and automatic sprinkler heads having valve caps held closed with fusible solder.

Whatever may have been the merits of the earlier types of sprinklers, the first commercial automatic sprinkler was manufactured and sold for practical service by Parmelee, of New Haven, under patents granted to him in 1874. Following him came Barnes, Grinnell, Buell, Neracher, Hill, Clapp, Kane, Mackey, Stratton, Gray, Hibbard, Meloon, Swan, and a score of other able mechanicians, most of them adding something to bring the sprinkler head and the automatic fire protective system, as a whole, to its present state of perfection.

The development of the automatic system of fire extinguishment, was largely stimulated, from the years 1875 to 1880, by the vital necessity of securing immunity from fires in New England textile mills, most of which were located in small towns and outlying districts generally removed from public aid. The rate on cotton mills not equipped with automatic sprinklers, was then about 3 per cent., while these same mills and mills similar to them, equipped with standard systems of automatic fire sprinklers, are now carried at $\frac{1}{10}$ of 1 per cent. There are now something like 10 000 establishments, valued at about \$3 000 000 000 protected with automatic fire sprinklers, and there are recorded instances where the automatic sprinkler has worked successfully in various parts of the world in something over 10 000 fires, with no failures. Of the fires in

America, nearly one-half have been extinguished so quickly and with so little damage that no claim whatever was made upon the insurance companies. The average loss per sprinkler fire is computed at $258.19, whereas, the average loss paid by the insurance companies on similar risks prior to the introduction of sprinkler protection is shown to be $7,361.00, making a total of at least $70 000 000 saved by sprinklers. Fires that are known to occur under sprinklers are now reported at the rate of about 50 per month, but the actual fires controlled or extinguished by sprinklers are undoubtedly more than twice that number, most property owners refusing to report fires extinguished by sprinklers, fearing that they might be subject to criticism and increased insurance rates.

In a list including over 5000 fires which occurred in buildings equipped with automatic sprinklers, compiled by our National Fire Protection Association, it is shown that in 93 per cent. of the fires the sprinklers were successful in extinguishing or holding the fire in check, and while this wonderful record is well known to insurance people, business men and manufacturers, it is not realized by the general public. The damage is invariably confined to a limited area, with a large pecuniary gain to the insurance companies. The owners and occupants of buildings have enjoyed a reduction in the cost of insurance of from 25 to 75 per cent. in addition to the comparative freedom from interruption to business, often more serious than the actual fire loss.

The most profitable portion of the fire insurance companies' business is now being derived from low-rated sprinkler-equipped risks, which, when so equipped, are classified as non-hazardous.

The approximate cost of equipping a building ranges from 5 to 10 cents per square foot of floor space, and, where circumstances require it, the sprinkler companies will equip a building, and take, as their compensation, the money saved in the insurance premiums for the six or eight years following the completion of their work.

While our state governors' recent conference considered

ways and means by which to conserve our national resources, there was apparently never a thought of the immensity of our garnered resources, finished and assembled into our thousands of buildings the country over, and no suggestion as to how the wealth in them, represented by our quarter billion annual fire waste, might be saved. In its relation to the present and future prosperity of our country, hardly any economic subject equals in importance, the elimination of fire losses.

PURPOSE AND DESCRIPTION OF THE SYSTEM.

The special purpose of the sprinkler is to arrest a fire in its incipiency through the agency of the heat of the fire itself. The system consists of lines of piping carried through the building near the ceilings, from 8 to 10 ft. centers, each head covering something like 50 to 100 sq. ft. of floor space. In case of fire the heat at once rises to the ceiling, where the temperature soon rises sufficiently to melt the fusible solder, releasing the valve of the sprinkler and profusely distributing the water on the fire.

Sprinkler equipments are of two general classes, the wet pipe system, in which the water is always in the pipes under the direct control of each separate sprinkler head, and the dry pipe system, in which the water supply is interrupted beyond the reach of frost and controlled by an automatic valve which intervenes between the outside supply and the system of sprinkler pipes within the building. Wet pipe systems are used where there is no danger of freezing, while dry pipe systems must be used in open sheds, cold storage warehouses and where water in the pipe is liable to freeze. In the wet pipe system an alarm check valve is used at the base of the main riser or supply. The automatic sprinkler system has been arranged to constitute a fire alarm. For sounding an alarm a variable pressure alarm valve is made to serve the purpose as effectually as the thermostat system. The flow of the water is utilized to operate the alarm, but unless the alarm valve be built on proper principles, the variable pressure in the water supply pipe may cause the alarm check valve to open and close

and give false alarms when there is no fire. An alarm valve of proper design should automatically discharge all excess pressure caused by water ram, and not have its alarm mechanism affected except by a steady flow of water such as occurs when there is an opened sprinkler head.

In the dry pipe system, air under moderate pressure is carried within the pipes to keep the automatic valve closed and exclude the water. When one or more sprinklers are opened the air escapes from the sprinkler pipes, the dry pipe valve is at once opened by the outside water pressure, an alarm is rung, and the water instantly fills the sprinkler pipes and is discharged upon the fire from every unsealed sprinkler. It is now generally admitted that a dry pipe system is about as simple in all respects and as sure in operation as the wet pipe system. Dry pipe valves are generally built on a differential principle of about eight to one, so that 1 lb. air pressure, in the sprinkler pipes, is made to hold against 8 lbs. water pressure in the supply pipes. The dry pipe valve must be so designed that it will be sure to open when the air pressure is reduced, however light the water pressure may be.

An automatic sprinkler must embody three important features: Tightness, certainty of action, and security against water damage by the breaking of the solder joint. Sprinklers are generally made in brass and consist of a frame, a nozzle, and a soldered link or strut. When the fusible solder, holding the strut or link together, is softened by the heat of a fire, the strut falls apart and the valve, no longer held to its seat, is thrown off by spring pressure, aided by whatever water pressure there may be within the sprinklers. The escaping water dashes upon the deflector and is scattered in all directions in the form of spray. Sprinkler heads are made with different solders. In all ordinary places, sprinklers fusing at 155 deg. are used. In boiler rooms and other places where there is excessive heat and the temperature remains at 100 deg. or higher, sprinklers with a medium solder, melting at 286 deg., are used. In dry kilns and other special places where there is a very high tempera-

ture, probably exceeding 200 deg., sprinklers with a hard solder, melting at 360 deg., are used.

Sprinklers are arranged to cover every part of the building, including stairways, elevators, platforms and concealed spaces. In buildings of standard mill construction, one row of sprinklers should be placed in the center of each bay, the space between the sprinklers varying according to the character of the risk.

In buildings with open joisted ceilings, they should be staggered and placed not more than 7 or 8 ft. apart on lines at right angles to joists and from 9 to 10 ft. apart on lines with joists. When bays are wider than 10 ft., it is customary to put two rows of sprinklers in each bay. In spaces directly over storage bins or racks, or immediately surrounding stairways, elevators, or large belt openings, extra nozzles should be placed to secure effective protection. The sprinkler head should also be placed above the pipe that it may not catch sediment, that it may drain when the system is emptied, and that the pipe may shield the sprinkler. The sprinkler should be placed so that its deflector will be not less than 3 in. nor more than 10 in. below ceilings or bottom of joists. The size of pipe used in a sprinkler equipment generally ranges from ¾ in. to 6 in., the National Fire Protection Association having published a schedule of pipe sizes, and based on having a practically uniform loss of pressure, due to friction in the several sizes of pipe, with any assumed average discharge from the sprinklers allotted to each size pipe.

The utmost possible simplicity should be observed in the layout of a sprinkler system, indicator gate and check valves should be placed at the connection to the city water main, at the tank, at the fire pump, at every source of supply, and all checks should open toward the sprinklers, thereby insuring a supply from the source having the greater pressure. Automatic sprinkler systems are subject to very little depreciation except in plants where there are acid and corrosive vapors.

Two water supplies, one of which should be automatic and capable of furnishing water under heavy pressure, are

essential and may be furnished from either of the following combinations:

Reservoir pressure from either public or private mains, and fire pumps.

Reservoir pressure and elevated tank.

Reservoir pressure and air pressure tank.

Elevated tank and fire pump.

Public water from two streets.

In addition to a double supply, a hose inlet to the sprinkler system, fitted with a straightway check valve, may be made for connection from a steamer of the public fire department.

Where city water under good pressure is available, an independent connection should be made with the street main equal to, or greater in capacity than the main upright supply pipe. Where an elevated tank is used, it should be placed at such an elevation that its bottom will be at least 20 ft. above the highest sprinkler head in the system which it supplies. In plants of moderate size, a 10 000 gallon tank is used; in larger plants, or where the second supply is limited, larger tanks, ranging from 15 000 to 50 000 gallons capacity, are used.

Tanks may be placed on an elevated structure over the roof, in a tower which forms a part of the building, or on top of a steel structure placed in a mill yard. The tank connection should project 4 in. above the bottom of the tank to avoid sediment, and the tanks and connections should be protected from freezing by proper means. The fire pumps used in connection with sprinkler systems are all built according to the underwriters' standard. upon specifications prepared by the Associated Factory Mutual Insurance Companies, May 20, 1893.

Early forms of sprinklers were in the shape of roseheads or hollow, perforated, spherical-shaped bodies, but experience soon proved that such small openings would be stopped up by dust, or by the sediment or scale from within the pipes. All approved sprinklers of the present day consists of an open outlet ½ in. in diameter, with a deflector, by means of which the stream of water is broken into spray and effectively distributed on the ceiling above and on the floor below. A sprinkler of

this kind under 10 lb. pressure, will discharge approximately 17½ gallons of water per minute; at 30 lbs. pressure, 30 gallons per minute, and at 100 lbs. pressure, 58 gallons per minute. The water distributed from automatic sprinklers is more effective than that given by the heaviest hose stream, the effect being that of a water blast 10 to 40 times more severe than a heavy rain fall. Heat from a fire rises, spreads under the ceiling in advance of the spread of fire and opens neighboring sprinklers whose spray over-reaches and completely surrounds the fire, confining it to its place of beginning.

We probably all agree that we burn up altogether too much property in this country, and my feeling is, that in just so far as any man is able to reduce our fire loss he is a public benefactor and the best kind of a helper to his fellow citizens.

The gist of our conviction and of our argument is that it is always better to pay for the prevention or extinguishment of fire than it is to distribute fire losses.

The immortal Shakespeare concisely puts it:

"A little fire is quickly trodden out, which,
Being suffered, rivers cannot quench."

*(NOTE: The statement, on page 322, relating to the quantity of water which might be evaporated by a burning floor, evidently refers to heavy warehouse or shop construction, where the amount of lumber in the floor system would be the equivalent of a cubic foot or more for each square foot of floor area.—Ed.)

DISCUSSION.

Chairman G. E. Flanagan: I was pleased with the emphasis the speaker laid on the fact that a fire is a loss to the community. Many people who are not property owners, might be led to think that they are not interested in property destruction, but they do take part in the loss.

Mr. Neracher: Answering the Secretary's questions in reference to material used for the valve seats, and as to the melting point of the solder: Glass is used because it is non-corrosive and not affected by acid and other fumes to which

the sprinklers are sometimes subjected. The discs are cast smooth, and not ground. They are tested by being heated in very hot oil and then plunged into ice water; only those discs which come through this test uncracked are used.

The solder used melts at 155 deg. fahr. A softer solder, melting at 117 deg., can be made but it lacks the strength necessary for constructive purposes; the higher fusing point is sufficiently sensitive.

Mr. J. B. Hardie: With an automatic sprinkler installation, is there any advantage in having a building constructed on fire-proof principles; would the insurance rates be any less than on a cheaper class of structure having the same protection? As the greatest danger from fire generally exists in the contents of the building the question suggests itself, as to whether structures having this protection could not in many cases, be of a more economical construction.

Mr. Trimble: The insurance rates on an open joist building would probably be 25 per cent. higher than on a fire proof or slow-burning structure.

Mr. F. C. Schatz: One cannot help being impressed with the importance of well equipped sprinkled buildings in the congested business district. A fire originating in one building, may not only prove disastrous to the building in which it originates, but also jeopardizes surrounding buildings. I have in mind a certain business house that had to face a fire from neighbors on three sides and at different times, and until the buildings were either removed or sprinkled, there was always a feeling of unrest.

The City of Pittsburgh today has a water supply of sufficient pressure and quantity to afford exceptional advantages to sprinkled buildings averaging about 125 ft. high. I refer particularly to the primary sources of supply. It is quite generally understood that any sprinkled risk can be made to operate entirely satisfactorily by means of a secondary or even a third supply of water; secondary supplies usually being tanks placed upon the roof, and the third—fire pumps. The owners of a certain down-town building which is equipped

with outside sprinklers on all four sides, have repeatedly made tests of the water supply, and found that they were able to operate all outside sprinklers at one time with a loss of less than 5 lbs. from the base of the building to the roof.

An ordinance is now being prepared, to be presented to councils, that will provide un-metered connections to all who are equipping their buildings with sprinkler systems. It is my opinion that anything that will tend to a co-operative spirit in the matter of fire protection, is a step of lasting benefit to the community.

Mr. Neracher: The point just made about the city water supply is very important and the suggestion has been followed in other cities. Officials who have charge of water works stations have become convinced that in every case where a fire can be handled by means of automatic sprinklers it will be put out more quickly and less water will be used.

Mr. Lee C. Moore: I am somewhat astonished at what I hear. Is it possible that we have men in the City of Pittsburgh, perhaps members of our councils, who are so narrow minded that they would think of metering water for fire purposes?

Mr. Neracher: I am not familiar with conditions in Pittsburgh, but I know that private water companies do insist upon metering water so used.

Mr. W. C. Hawley: I shall have to take issue with the statement that the city should not install meters on pipe lines to be used for furnishing fire protection. The subject has been discussed at great length, especially at the meetings of the New England Water Works Association. The water departments and the water companies throughout the eastern part of the United States have been trying to solve the problem of how to find a practicable method of furnishing water for fire protection and measuring the water taken from the fire lines, either by waste, leakage, or "surreptitious appropriation." The position of the insurance men was that the fire lines should not be metered. The water works men insisted that there should be some device by which all the water necessary

for fire protection could be supplied, but that the immense quantities of water allowed to go to waste or stolen should be measured and paid for. The result was the design of what is known as the detector meter. This is not really a meter, but consists of a check valve in the main fire line with a comparatively small metered by-pass. The check is so constructed that it remains closed until the pressure on the factory side of the check is about 10 per cent. less than the pressure on the side toward the main, when the check valve opens and water, to the full capacity of the pipe, is delivered to the fire lines. Any water drawn at other times passes through the by-pass and is measured by the meter. There is also a small meter, the tap for which is covered by the check when it is closed, but as soon as the check lifts from its seat, a small stream of water is discharged and measured by the small meter, from which it is possible to estimate the length of time the check valve was open. On a 6, 8, or 10 in. detector meter, the by-pass is 3 in. in diameter with a 3 in. meter, and the quantity of water which may be drawn before the check valve opens will range between 200 and 300 gallons per minute. Thus it will be seen that the detector meter is a differential check valve with a metered by-pass, and it has proven entirely satisfactory. These meters detect any leakage from the pipes and save immense quantities of water. In a recent test of an unmetered fire service, it was found that something over three cubic feet per minute was being taken from the fire lines. In another case 20 000 gallons per day were being taken, and while part of it was leakage, a considerable part of it was being "surreptitiously appropriated." The detector meter furnishes the only method of knowing the exact condition of the fire lines, the daily reading of the by-pass meter indicating any leakage which may exist. For this reason, the insurance companies should rather co-operate with the water companies to secure the installation of detector meters.

Some years ago, an estimate was made of the amount of water used in Pittsburgh for fire protection, the idea having been advanced that when a filter plant was installed, it would

be necessary, on account of the tremendous amount of water used for fire protection, to have a separate system of pipes, one for the filtered water and one for the raw river water for fire purposes. After careful investigation, it was found, however, that the water used in fighting fires amounted to about ½ pint per person per day, an amount too small to be considered. Hence, it is not a question of gallons; it is a question of the cost of "standing ready"—having mains and reservoir capacity sufficient to deliver a large quantity of water at any given locality whenever it may be needed. The other day a gentleman wanted a 6 in. fire connection to a property worth at least half a million dollars. He was willing to pay the cost and generously added that he would pay for any water that was used. He wanted our plant to stand ready to furnish water at the rate of over a million gallons per day, he might not use a gallon of water for years, but did not expect to pay anything for the service which would result in such a material saving in insurance on his plant.

Again, as to the cost of furnishing fire protection. Suppose a block of 20 houses is to be supplied with water for domestic use. A 1½ in. pipe along that street with ordinary pressure would be sufficient, but if it is desired to furnish fire protection, a 6 in. pipe plus the cost of a fire hydrant is necessary, and from that block to the reservoir, every foot of pipe must be designed of sufficient capacity to provide for fire protection as well as for domestic service. In fact, in designing the ordinary system of water works for a small town, the water necessary for fire protection is the controlling factor in computing sizes of pipe, the water for domestic use being comparatively insignificant. Besides this increase in cost of pipe, there will be an increase in capacity of pumps, intakes, force mains and reservoirs. The increased cost of a water works system to furnish fire protection, over the cost of a plant covering the same territory to furnish water for domestic use only, amounts to from one to two-thirds of the total cost of the plant for the combined service. On this increase of cost must be computed interest, depreciation, maintenance, taxes

and something for sinking fund, and the total sum of these is the annual cost of furnishing fire protection. Obviously, such an expensive service cannot be furnished for nothing. Perhaps, as a matter of good civic policy, we should not criticise the municipality in furnishing fire protection free and collecting its cost by an added charge on the domestic service or by taxation. As a matter of equity between tax-payers, however, the benefits should be equally distributed in proportion to the taxes paid. When factory or mill owners want a half mile of additional fire lines with a 10 or 12 in. connection to the pipes of the water works—a supply sufficient for a city of 6000 or 8000 people—and do not want to pay anything for it, it is only just to point out what the owners of that plant are getting for the taxes paid, and what their neighbor with a small property gets. I think the municipality should pay for the fire protection, whether it is a private company or a municipal plant which furnishes it. I should be equally opposed to placing the ordinary type of meter on a fire line, or measuring the water used for fire protection. I can see no reason, however, for the water department or water company having to stand the loss due to leakage, waste or the stealing of water from the fire lines; and surely, if the saving in insurance is so great as has been stated tonight, the person or firm benefited can afford to pay for it.

Mr. Schatz: The municipality owes to its citizens and their interests, fire protection. If it owns its own water works, it must naturally supply the water, and if the water works is a private corporation, the city must make arrangements whereby the private company supplies the necessary water. If the owners will install sprinkler protection and the city will give the water supply, it is certainly a condition which should appeal to both parties. By reducing the number of fires, the quantity of water per capita is naturally reduced, and the water rates would govern in proportion.

The objection of owners to using meters on sprinkler lines, is not a matter only of cost, but a matter of absolute certainty of supply. The installation of meters would jeopardize, to a

certain degree, the efficiency of the sprinkler system, and I have heard it said by at least six of the largest users of sprinkler equipped buildings, that they are willing to file a bond if called upon, to assure that they will not use, nor allow to be used, water from a sprinkler system for any other than fire purposes. They are willing to file a complete set of drawings showing all their piping and manner of using the water, and further, will be willing to suffer a penalty for violation of the proper use of the same.

Mr. Hawley: I would not be understood as charging the management of large industrial plants with the stealing of water from fire lines; there are very few in responsible authority in such plants who would knowingly countenance such a thing, and yet it occurs more or less in almost every large plant. In one case, the fire line had only been installed a matter of months, and we put an ordinary meter on a by-pass around the valve. When we were ready, I asked one of the officers to go and see the test. When the valve was closed, the meter started off at the rate of 20 000 gallons per day. Later, we found that the rate of registration varied materially, and we suspected that some of the plumbing was attached to the fire line, and later found that such was the case. I think that the managers of the concern did not have the slightest knowledge of it, and that is what happens in the majority of the large plants.

In the test previously referred to, where 20 000 to 30 000 gallons of water was going through the fire lines, a part of the water was going to waste. The owners did not know about it and might never have known, as it was a bad joint on a fire hydrant, and the water was draining into a cinder fill. Had there been a necessity for using that fire hydrant, they might have found that leak at a time when it would have proven very serious. I do not think that any reasonable objection can be made to the installation of detector meters on private fire lines.

A decision was rendered in May last, by the Supreme Court of the State of Massachusetts, in the case of the Shaw

Stocking Company vs. the City of Lowell, in which the Court holds that a city or town has the right to install a meter on water pipes constituting a private fire protection system in a mill or other private plant at the expense of the owners of the buildings. The court also holds that a city is under no legal obligation to furnish free water to a mill, even for fire protection. This decision is mentioned in the June number of "Water and Gas Review," page 14, and there is one very important point in this decision, which it would be well to mention, as follows:

"In this case it has been found by the Court below, with evident correctness, that the plaintiff is under no legal obligation, by contract or otherwise, to furnish the plaintiff with water for its private fire-service system. * * * Both upon principle and authority we are of opinion that under circumstances like those before us it is not unreasonable to require the installation of a meter at the plaintiff's own expense in its private fire service pipes. Nor can it be said that this regulation imposes undue burden upon the plaintiff. The defendant has afforded reasonable means of extinguishing fires by public hydrants; if the plaintiff desires, in addition, a private system for the protection of its own buildings, it is not unfair for the defendant to impose, as a condition of supplying, without other charge, water to make this system available, the requirement that the plaintiff shall take this water only through a meter to be put in at the plaintiff's expense."

This part of the decision answers all of the peculiar reasoning on the part of the fire insurance men to the effect that a municipality is bound to furnish unlimited fire protection without charge and also bear all of the loss due to leakage and unlawful taking of water which may occur on the fire lines.

In the same number of "Water and Gas Review," on page 26, will be found an interesting paper by Mr. R. J. Thomas, superintendent of the Water Works, Lowell, Mass., on the subject, "Proper Working of Detector Meters." This was a paper read at the 28th annual convention of the American Water Works Association, at Washington, D. C., last month.

Mr. Moore: I think the point intended is this—that with the automatic sprinkler system it is possible with 50 gallons of water to prevent a disastrous fire, whereas, without the sprinkler system and without the 50 gallons of water, it might cost the city 50 000 gallons to stop that conflagration. Mr. Schatz's point is this—that he does not think people concerned like they are should be charged for what little water it takes to work the system.

I want to say further that if the city is supplied by private water works companies, the city should pay them for furnishing an establishment for that purpose free. I do not think a private corporation should bear the expense, but the municipality should.

Mr. Neracher: I perfectly agree with my friend that meters are a good thing from a water works standpoint. But I have never known of a fire protection engineer who did not much prefer that any kind of meter be left out of the main supply of an automatic fire sprinkler system. I was in Chicago only a few days ago and talked with one of the leading engineers in the Western Factory Insurance Association, a man who is authority on most of the things that have to do with automatic fire prevention and control, and he said that he much prefers the water main to be kept entirely free from meters. My personal opinion is that a meter of any type makes an added complication and introduces an obstruction and resistance which, strictly from a fire protection standpoint, would much better be omitted.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXIV OCTOBER, 1908 No. 7

REGULAR MEETING,

September 15th, 1908.

President James K. Lyons,

In the Chair.

THE DEVELOPMENT OF TELEPHONY.

By Sergius P. Grace,*
Member.

The transmission of intelligence by the telegraph had, by the middle of the last century, reached a fair state of development, and it was but natural that the inventors of telegraphic apparatus should turn their attention to the creation of telegraphs which would not require skilled operators. This was accomplished in the early 70's by the invention of the printing telegraph whose step by step mechanism would reproduce at the receiving end of the line any character or letter struck at the transmitting end. One of the earliest successful types of printing telegraph was invented by Elisha Gray. Scientists and laymen alike had dreamed of the long distance transmission of articulate speech, but its accomplishment seemed so far in the future that when the printing telegraph was developed it was hailed as one of the great inventions of the century, and it was predicted that it would have a most profound influence upon the business and social relations of the country.

* General Superintendent of Plant, Central District and Printing Telegraph Co.

As far back as 1874 the City of Pittsburgh was supplied with a printing telegraph system, making use of the Gray printers. Many of the iron and steel companies had printers in their offices, connected to a central exchange located on Fifth Avenue in the First National Bank Building. These printers were operated by the Central District and Printing Telegraph Company, the "central district" part of the name referring to the messenger branch of the business. In figure No. 1 is shown the first Gray printing telegraph ever used in the City of Pittsburgh, and in figure No. 1-A the first subscribers' directory.

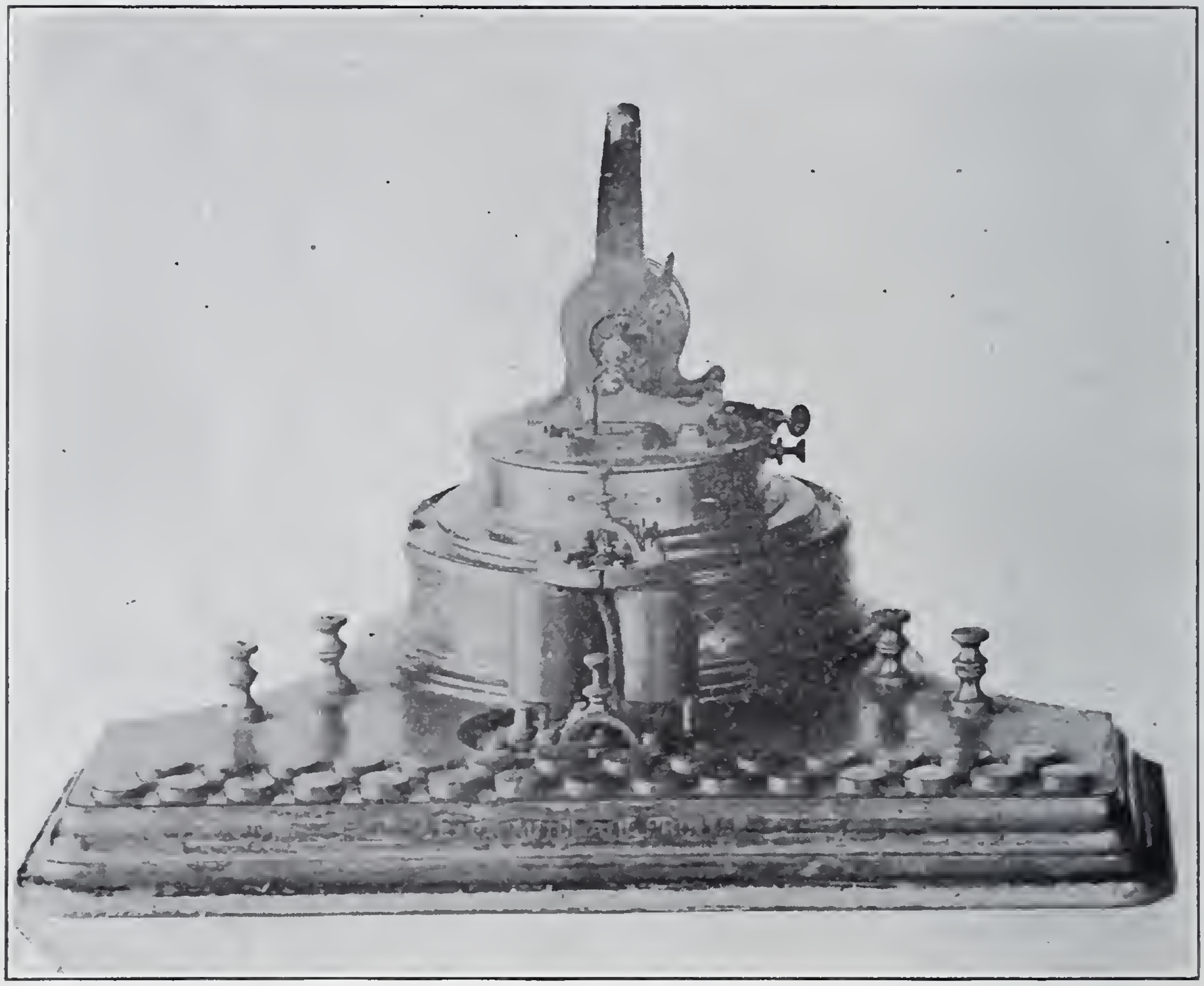

Fig. 1.

When in the memorable year of 1875, Alexander Graham Bell gave to the waiting world the masterpiece invention of the century, the electric telephone, there were many who considered it only a scientific toy; but the discerning ones saw that properly developed it was going to be the greatest labor saving invention of the ages. Among the latter was T. B. A.

—THE—

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[illegible]

The Central District and Printing Telegraph Company assumes no liability for damages for errors made in exchanging messages through its Central Office, but will use due precaution to prevent their occurrence by the employment of competent operators. Customers are cautioned to instruct their operators to use care both in sending and receiving messages, and in cases of doubt to have messages repeated.

The operators at Central Office are sworn not to [illegible]

Telegrams to be delivered by messenger will be charged for [illegible] rates: 10 cents for the first 15 minutes, or less; [illegible]

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WARING BROS
LOCKHART & FREW
COLUMBIA CONDUIT CO
PITTSBURGH ACID WORKS
PENN A SALT MANF'G CO

WESTERN UNION TELEGRAPH OFFICE
PAN HANDLE FREIGHT DEPOT
FORT WAYNE
PENN A R R
ALLEGHENY VALLEY FREIGHT DEPOT
CLEVE & PITTS R R

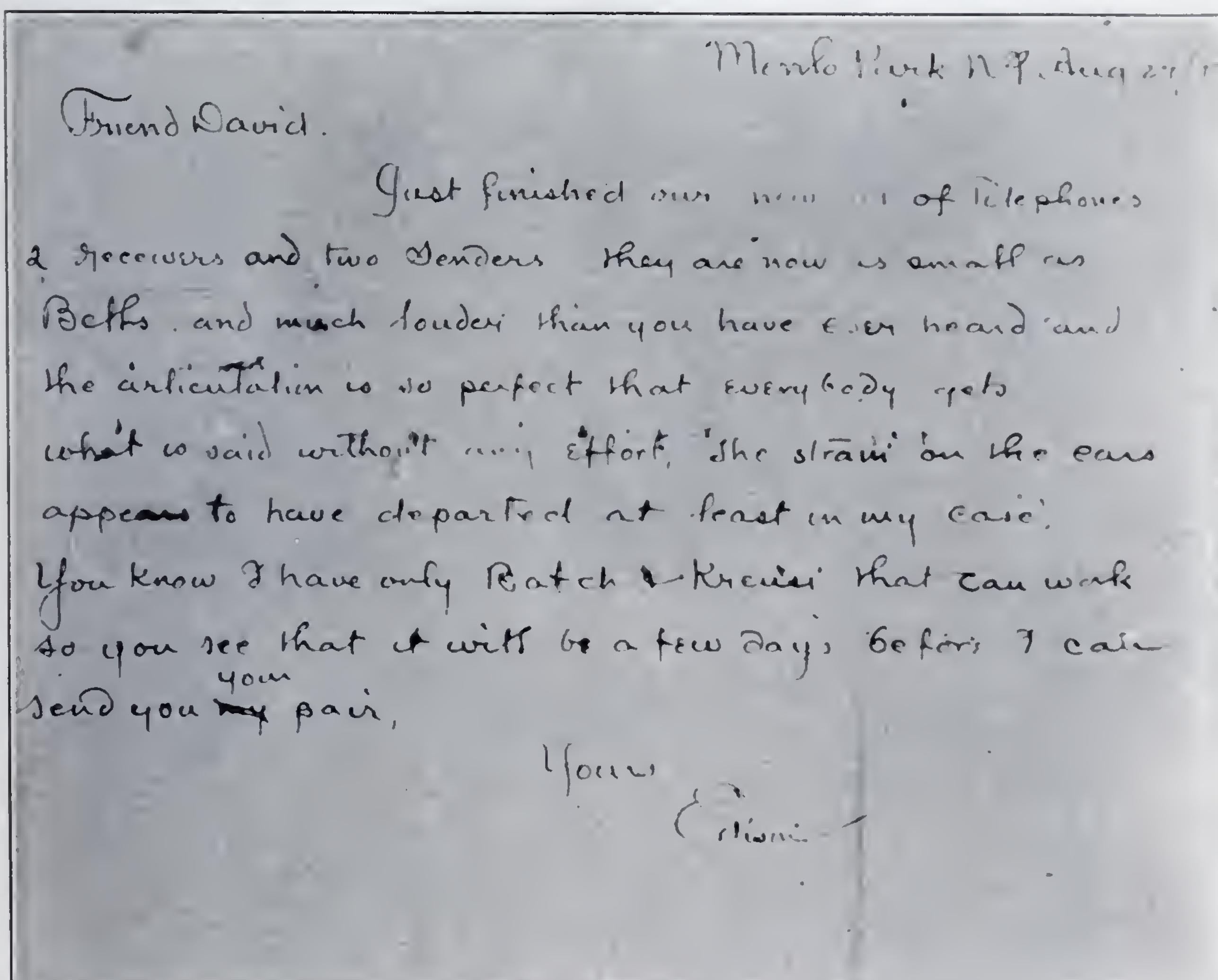
FIG. 1-A.

David, the President of the Central District and Printing Telegraph Company. In the fall of 1876 he investigated the electric telephone system of Bell, and shortly afterwards he witnessed a trial of a Bell telephone receiver in combination with the recently invented carbon transmitter of Thomas A. Edison. Mr. David, with his broad mind, instantly saw the possibilities of the telephone and determined that Pittsburgh should be one of the first cities in the country to exploit this invention. Having control of the lines of the Central District and Printing Telegraph Company he was in a good position to introduce the telephone. In the summer of 1877 Thomas A. Edison agreed to make for Mr. David two telephones for exhibition purposes in Pittsburgh. There were delays in the manufacture of these instruments because of the limited machinery and material at Mr. Edison's disposal, and several letters were written by Mr. Edison to Mr. David explaining the delay and asking him to keep up his courage. These letters were recently taken from an old file of the Central District and Printing Telegraph Company, and they throw an interesting side light on the development of telephony in the days when the carbon transmitter was being born. Mr. Edison has always had the reputation of being a hard worker, and this is borne out by his statement in one of the letters that he and his assistants were working 22 hours per day. In another letter he asks Mr. David not to be too critical regarding the first two telephones, for he had to make them with some old pieces of hard rubber and a pair of pliers. One of these letters is reproduced in figure No. 2.

The telephone exchange established by Mr. David represented the Western Union Telegraph Company, who at that time were fighting the National Bell Telephone Company for control of the telephone field. The Bell Company also established an exchange in Pittsburgh, but in the year of 1880, at the close of the famous litigation between these rival companies, the two exchanges in Pittsburgh were consolidated. However, the old name of the Central District and Printing Telegraph Company was retained because of the very favor-

able charter which it had secured from the state. This explains the peculiar name of one of the largest of the Bell licensee companies, and brings out the fact that originally it was chartered to exploit the printing telegraph.

From 1876 to 1886 the telephone all over the country had a struggle for existence. The telephones were of the crudest type, the switchboards were simply adaptations of telegraph boards, and the vast amount of iron wire strung on roof tops



Menlo Park N.J. Aug 27 77

Friend David.

Just finished our new [illegible] of Telephones 2 Receivers and two Senders they are now as small as Bells and much louder than you have ever heard and the articulation is so perfect that everybody gets what is said without any effort. the strain on the ears appears to have departed at least in my case. You know I have only Batch & Kruesi that can work so you see that it will be a few days before I can send you ~~my~~ your pair,

Yours

Edison

FIG. 2.

was a combination not productive of a telephone service such as would inspire the confidence of the public. Added to these handicaps the introduction of the electric trolley and electric light and power service made the grounded telephone lines extremely noisy by induction. As an example of the crude switchboards of early days a switchboard is shown in figure No. 3 which was made by Charles Williams in his old Boston

shop in the early 80's. This board was used for a number of years for a private branch exchange in the Dixmont Insane Asylum.

From 1886 to 1896 the various telephone companies, assisted by the engineering departments of the American Bell Telephone Company and the Western Electric Company,

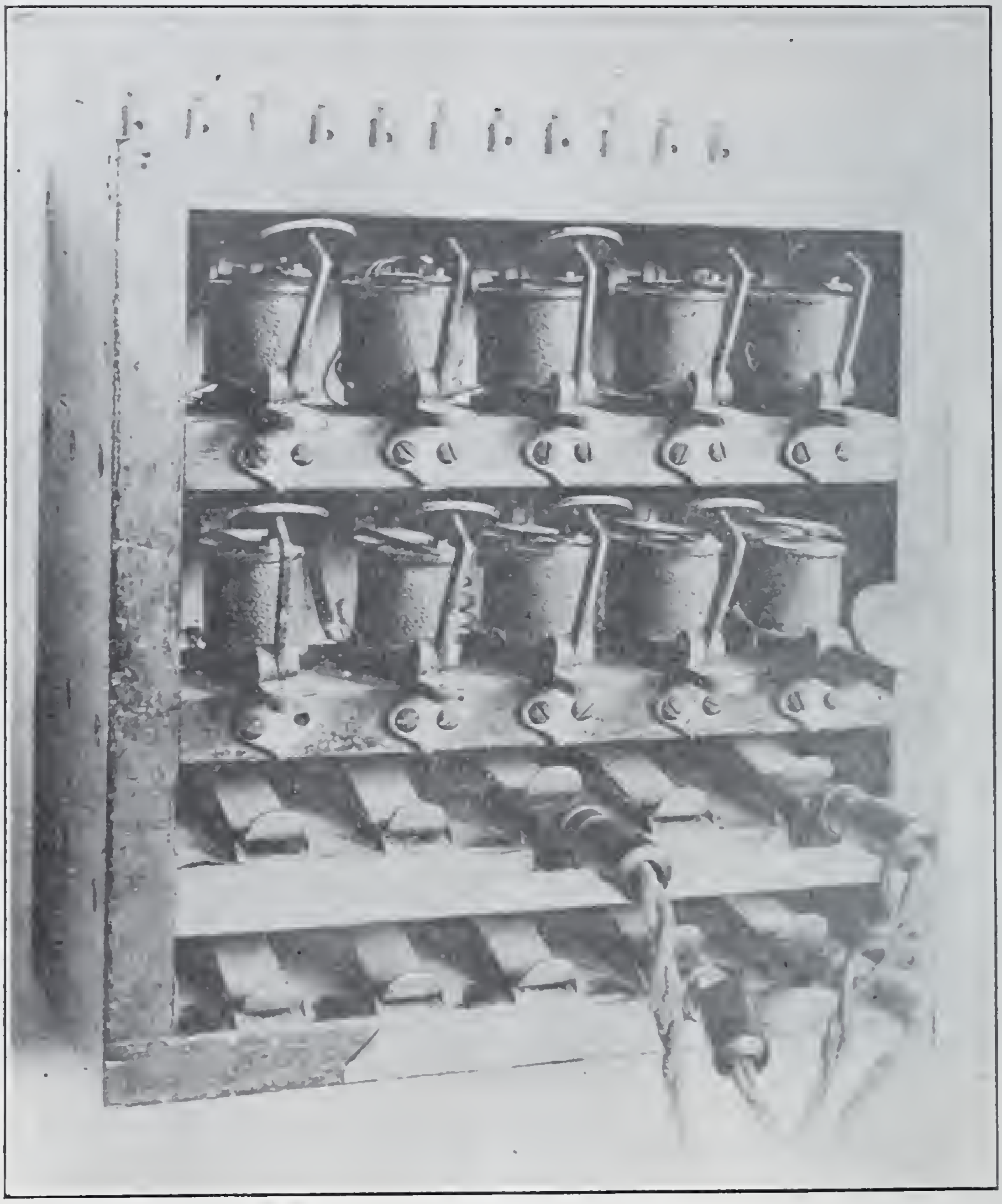


Fig. 3.

made heroic efforts to develop apparatus and lines suitable for the transmission of electrical energy for articulate speech. It was early found that iron wire, because of its high resistance and inductance, seriously retarded telephone speech, but copper wire could not be used because of its low tensile

strength. It was not until Thomas B. Doolittle, of the engineering staff of the American Bell Telephone Company, developed the process of hard drawing copper wire that copper could be used at all for outside lines in the development of telegraphy and telephony.

Even with the advent of metallic circuits many troubles were experienced with the telephone lines from external induction from electric light and power wires, making the telephone lines noisy, and from induction caused by neighboring telephone circuits, resulting in the phenomenon called "cross talk". A system of transpositions had to be developed which would keep the lines reasonably free from induction from outside sources and yet which would prevent "cross talk" from one telephone circuit to another. "Cross talk" is overhearing from one circuit to another, the current being induced electro-magnetically and electrostatically without metallic contact.

Because of the large number of wires required in telephony it became imperative to design a cable which would accommodate in a small space many hundreds of wires. After a long period of development work Mr. Patterson of the Western Electric Company, finally developed his paper insulated, lead covered, telephone cable, which still remains the standard of the telephone world.

The development of switchboard equipment and apparatus was also rapid in this period, and when the multiple magneto switchboard with self-restoring drops was invented it was considered by some that the limit of switchboard improvement had been nearly reached. In the early 90's it was clearly seen by discerning telephone engineers that to meet the demands of service in large cities a faster and more efficient type of central office switchboard must be developed than the old magneto. Furthermore, in the old magneto system, batteries were placed in each telephone for the operation of the transmitter, and an alternating current generator was supplied for throwing the drop at the central office. The maintaining of these thousands of

distributed batteries and alternating current generators was a severe burden upon the telephone companies, and unless they were well maintained poor service resulted. In fact the magneto telephone may be looked upon as a small power house in which there are means for generating single-phase alternating current and direct battery current.

One of the greatest difficulties with the old type boards was the lack of supervisory signals for the guidance of the operators. In the larger cities where it was necessary to trunk calls from one office to another, this was particularly exasperating and annoying. The time consumed by the operators on these trunk connections was expensive and premature disconnections were the rule instead of the exception. To overcome these objections the engineers of the American Bell Telephone Company and the Western Electric Company developed the modern central battery switchboard. This type of board has become the recognized standard of all the Bell telephone companies.

It is interesting to trace a connection through this type of switchboard. When the subscriber removes his receiver from the hook a tiny incandescent lamp on the face of the switchboard directly over the subscriber's line jack is lighted. The operator inserts into the subscriber's line jack a plug which is attached to a connecting cord. The inserting of this plug automatically extinguishes the subscriber's line lamp. The operator now depresses her listening key which connects her telephone with the subscriber's line and asks for the number wanted. A plug attached to the other end of the connecting cord is inserted into the line jack of the wanted subscriber and the operator depresses a ringing key which sends an alternating current over the line to ring the bell of the called subscriber. However, it should be said that before fully inserting the plug the operator touches lightly the rim of the called subscriber's line jack. If his line is busy the operator hears a click in her ear and will inform the calling subscriber that the line wanted is in use. It only takes a slight effort to plug into the called line after the test is made and

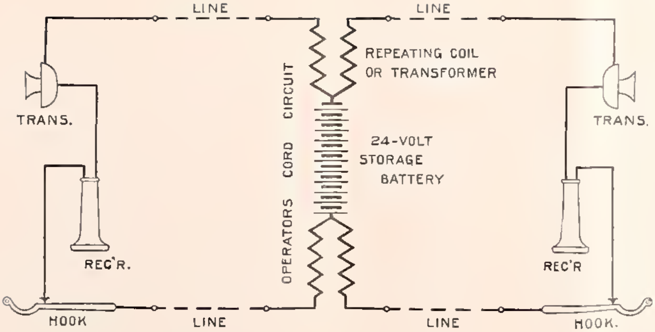


FIG 4

CENTRAL DISTRICT & PRINTING TELEGRAPH CO. FIG. 4

COMMON BATTERY SWITCHBOARD CIRCUITS

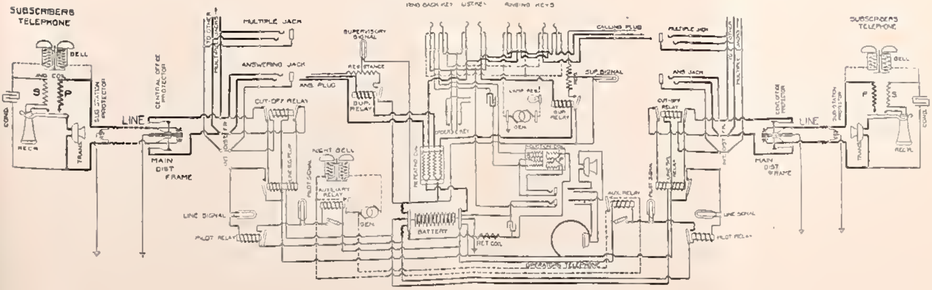


FIG .

the operator would rather do this than report the line in use. Many tests have shown that the operators make few mistakes in reporting busy lines.

When the called subscriber answers his telephone, a small supervisory lamp in connection with the calling cord is extinguished. When the subscribers are through talking and each hangs his receiver on the hook, supervisory lamps wired to the connecting cords are lighted and thus indicate to the operator that the pair of cords, and therefore connected lines, are no longer in use. She will then take down the plugs and both supervisory lamps will be extinguished.

Each operator in a large, central battery, multiple exchange has within her reach the line jacks of all subscribers in this exchange. This is accomplished by connecting every subscriber's line to line jacks placed every five feet along the face of the switchboard. A Grant local operator thus has within reach of her hand all of the 8000 line jacks of the subscribers connected to the Grant Exchange. However, if a Grant operator receives a call for a telephone number in another exchange, such as Highland, which furnishes service to East Liberty, the connection must be made over a trunk line. The Grant operator will repeat your number to a trunk operator in the Highland Exchange over what is known as an order circuit wire. The Highland operator will then assign a trunk which is to be used for this connection, and will make the necessary plug connections in the Highland Exchange. It is thus seen that all trunk connections require the services of two operators, although the trunk operator at the far end of the trunk does not converse at all with the subscriber, and acts only under the instructions and orders of the operator originating the call. When the subscribers who have been conversing over a trunk line are through with their conversation and hang up the receivers, automatic lamp signals are displayed before the operators, which show that the trunk is no longer in use.

All the current is supplied to the transmitters from one large central storage battery, as shown in figure 4. In figure

5 is shown a diagram of the connections from one subscriber's telephone to another, and it is believed this diagram will impress anyone with the fact that the transmission of articulate speech is a complex problem in the transmission of electrical energy.

A great majority of the people, and in fact many engineers, are unacquainted with the electrical principles made use of in telephony, and do not understand that telephony and electric light and power distribution are similar problems in the transmission of electrical energy. This similarity was clearly brought out a few years ago by Charles Proteus Steinmetz, of the engineering staff of the General Electric Company, in an address delivered before the American Institute of Electrical Engineers, in which he said as follows:

"The problem of transmitting alternate currents leads to two very distinct phenomena and problems, that of transmitting very large powers at very low frequency relatively, at high voltages with the so-called electrical power appliances, and then the transmitting of very small powers at very high frequency at very low voltage. That is telephony. The theoretical aspect of the problem is the same, but they have to be considered entirely different."

In the development of the central battery switchboard there were required the creation of many new types of apparatus. Special types of charging dynamos had to be developed which would charge the storage batteries without introducing noises in the thousands of connected telephones. New types of electric transformers known as repeating coils had to be designed which would have a high efficiency for the high frequency currents made use of in telephony. Then, again, many hundreds of different types of relays or circuit closing devices were necessary. In some of the circuits there may be several dozen contacts for the telephone current to pass through. Any one relay falling out of step will interrupt the connection, and yet some of our subscribers on very rare occasions become exasperated with the whole telephone system because one of these many hundreds of relays fails to open

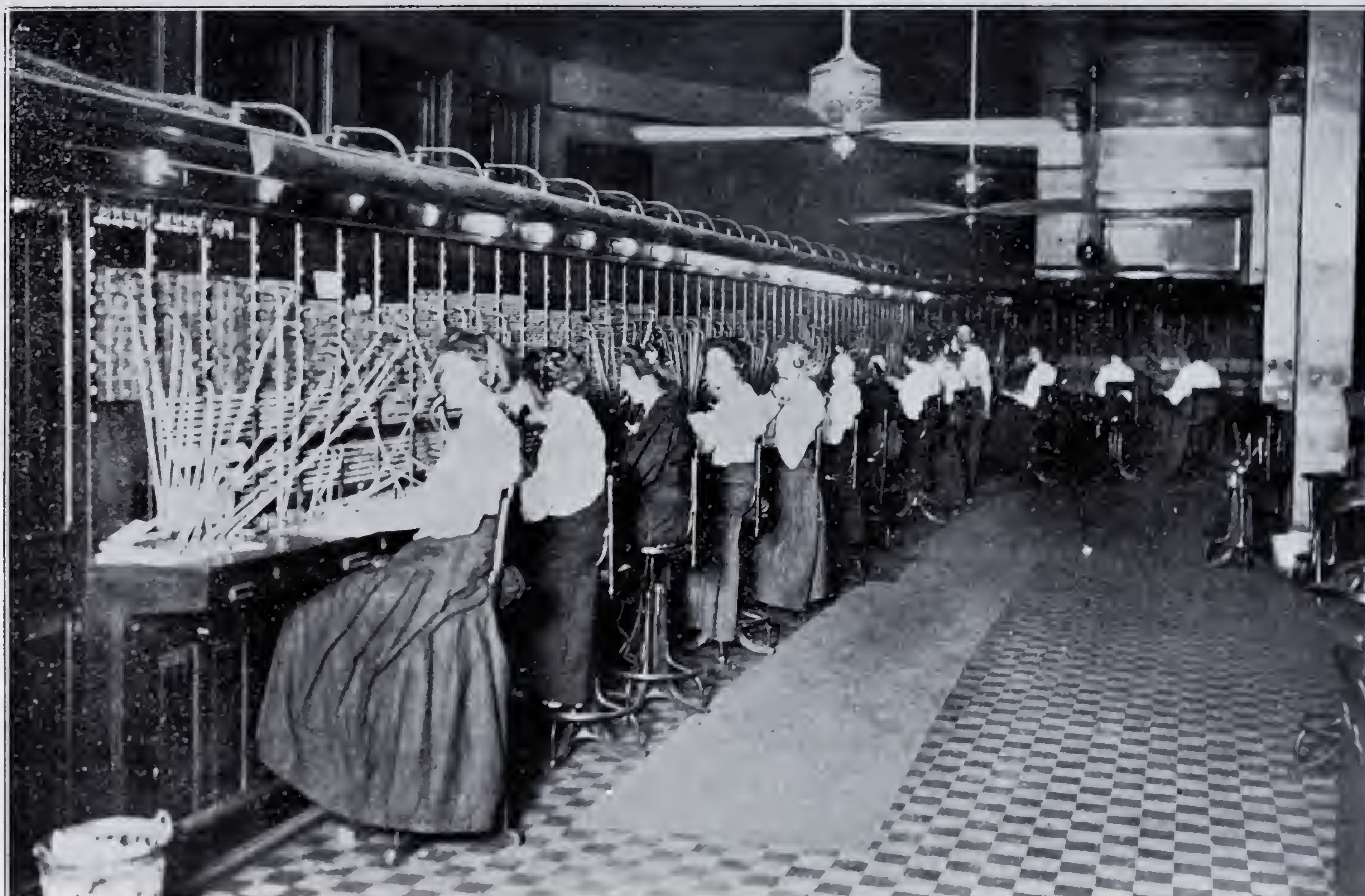


Fig. 6.

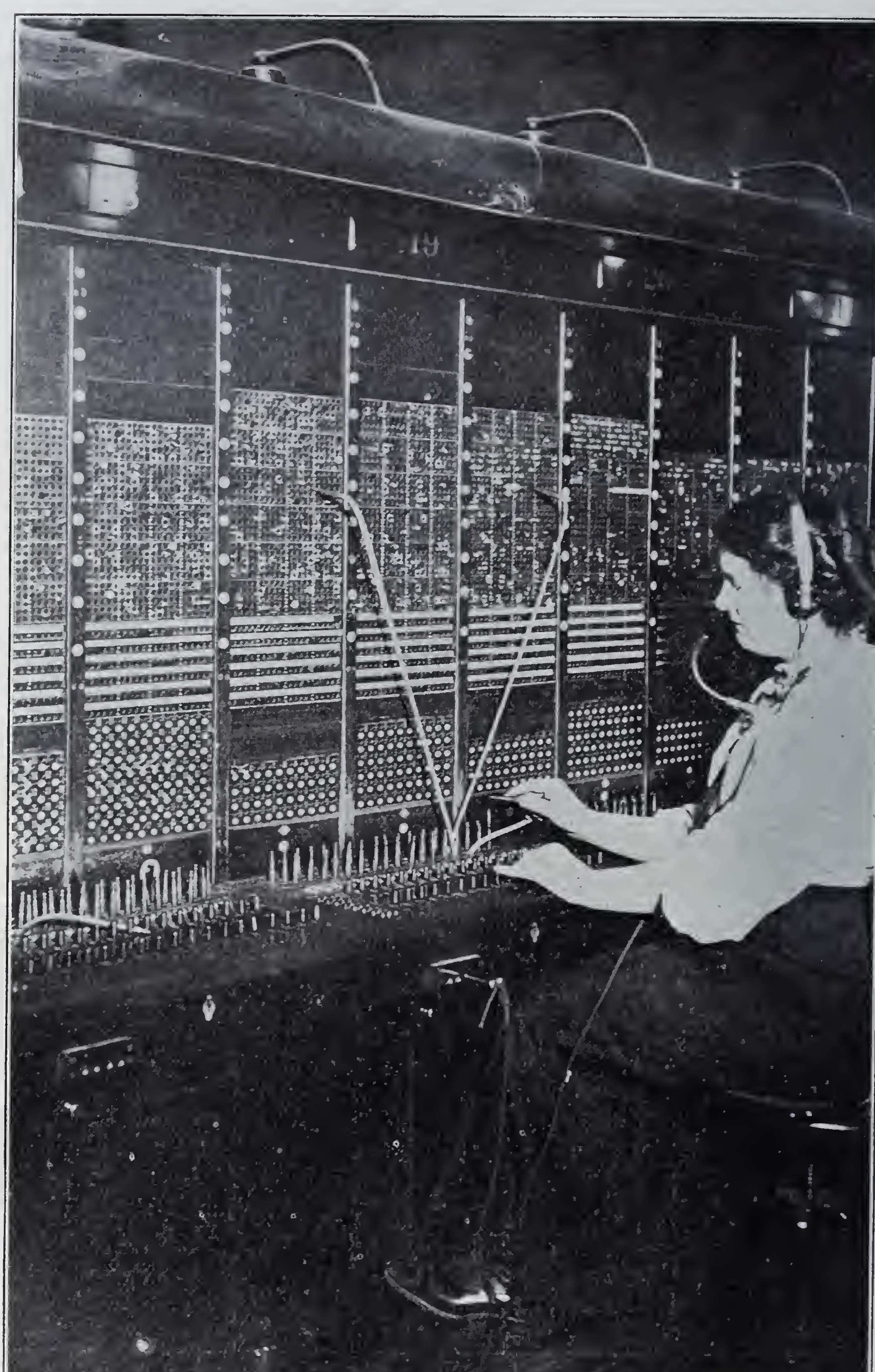


Fig 7.

its contact at precisely the right moment. And strange to say, the public nearly always blames the operators, never stopping to think that perhaps a portion of the delicate and elaborate electrical mechanism in the line is at fault. In figures 6 to 11 are shown types of modern central battery switchboards in connection with cable entrances, distributing frames, power plants, etc.

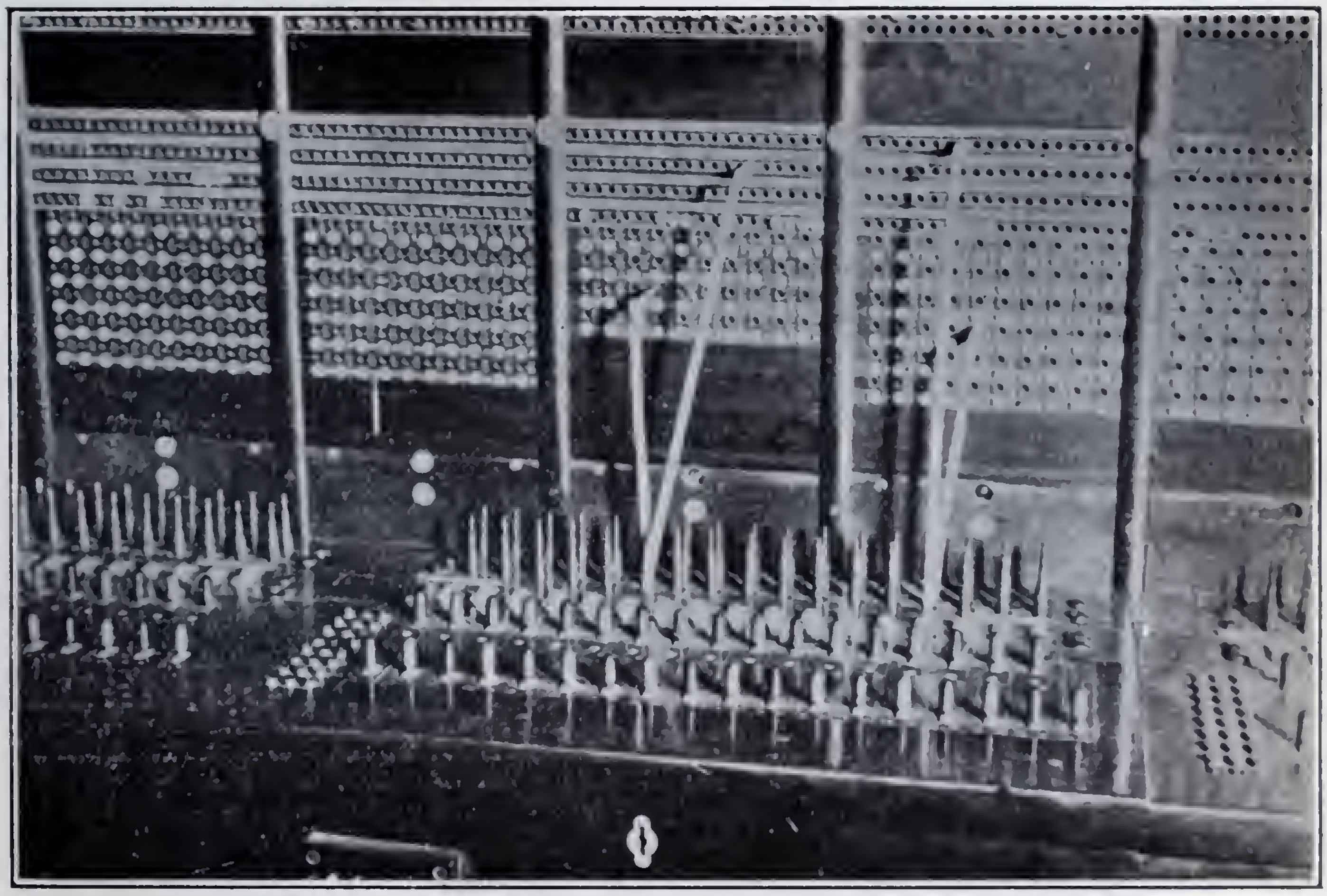


FIG. 8.

In the last eight years there has been great development in the methods of outside construction. In the early days telephone lines were naturally modeled after the existing telegraph construction. The large number of circuits required and the different character of the transmitted current has led to special types of construction for telephone work. In the large cities, in congested centers, underground construction is employed, using cables containing as many as 600 pairs of wires, with direct connection to the subscribers' premises by means of interior block wiring. This is shown in figure 12.

Conduits are also built along the main feeder routes to the outside districts, but the distribution is effected at right angles to these feeder routes by neatly designed aerial cables. These cables contain from 50 to 200 pairs of wires and are tapped about every other pole, so that the service wire to the subscriber's premises may be made of a minimum length. This method of connection is shown in figure 13. It is interesting to note that one of the first underground systems for the distribution of telephone wires anywhere in the world was installed in 1882 on Fifth Avenue, between Wood Street and Liberty Avenue. Perforated porcelain blocks were laid on edge in a

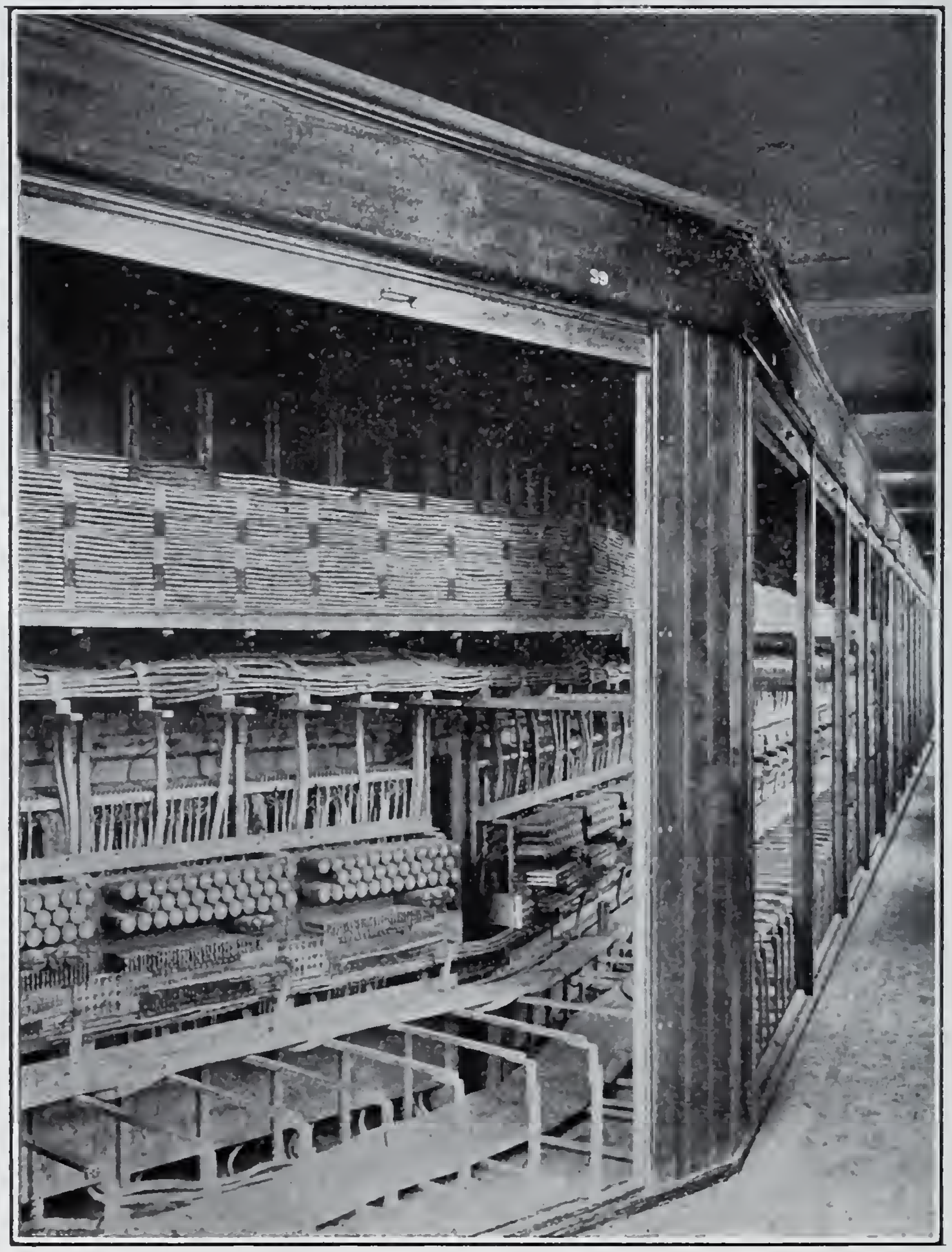


FIG. 9.

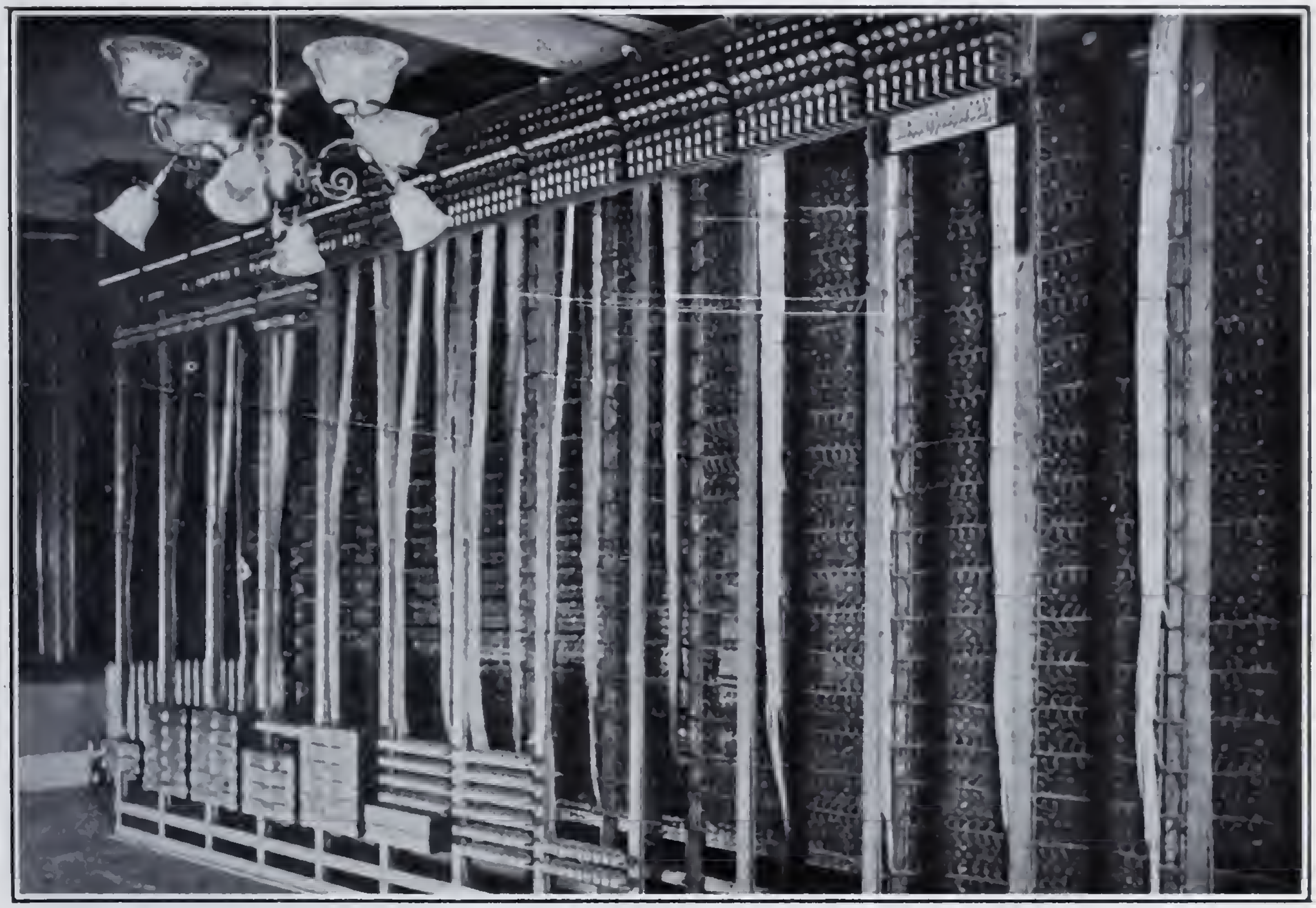


Fig. 10.

wooden box and annunciator wire pulled through the holes, after which the box was filled with pitch. These wires gave service for nearly a year, until the insulation finally failed. A photograph of some of the original blocks is shown in figure 14.

It had been known for some time that even with very powerful transmitters the range of telephone transmission had a distinct limit, and the increasing of the transmitting power had but little effect in increasing the volume or improving the articulation of the transmitted speech. The telephone current has such a high frequency that the distributed capacity in a long telephone line is very active in attenuating and distorting telephone speech. Remembering that the telephone current alternates from 100 to 2000 times per second, the difficulty of obtaining a sufficient quantity of electricity at the far end of a long circuit to properly operate the receiving telephone apparatus can easily be appreciated. If we had to deal with the resistance of a telephone circuit alone, and the

capacity and self-induction were absent, the current received at the far end would be strictly proportional to the resistance of the circuit; but when distributed capacity is combined with resistance and the self-inductance is very small, the waves of current are rapidly attenuated and besides distorted, for the higher frequencies, corresponding to the over-tones of the human voice, will not be attenuated at the same rate as the lower frequencies, and therefore the received speech will appear unintelligible or distorted to the listener. By means of an oscillograph, the curves shown in figure 15 were taken. Curve A shows the form and amplitude of current of the vowel "e"

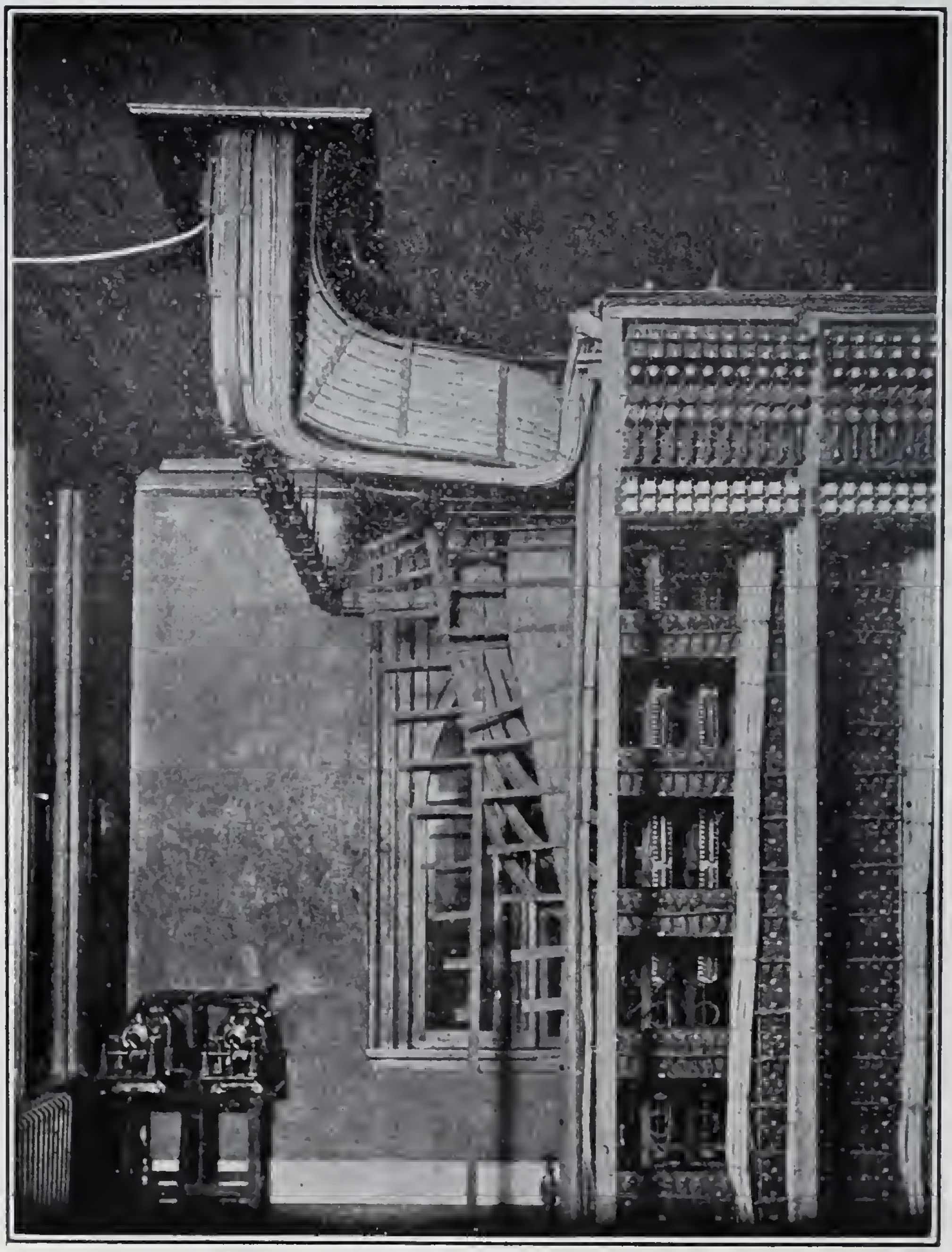


FIG. 11.

Fig. 12.

at the transmitting end of a 1000 mile open wire line, and curve B shows the form and amplitude at the receiving station.

Mathematical electricity had pointed out some years ago that the distributed capacity of a telephone circuit might be counteracted by inductance placed in the circuit, but it remained for Doctor Pupin, of Columbia University, to show us how to place self-inductance in a telephone circuit so as to limit the

FIG. 13.

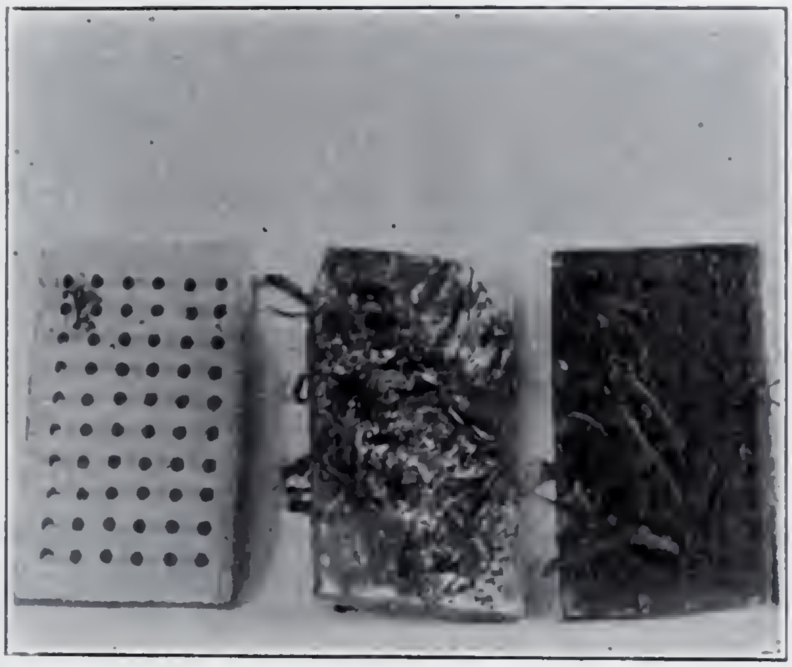
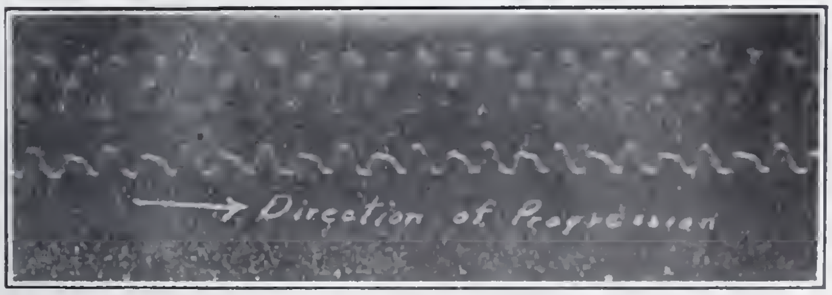


Fig 14.



A

B

Fig. 15.

effect of the distributed capacity. These self-inductance coils are known as loading coils and are being used today in thousands of lines of the Bell telephone companies. The placing of these coils in a telephone circuit will increase the range of good telephone transmission over the circuit from three to five times. This invention has been of the greatest importance to telephony and its value cannot be overestimated: In figure 16 is shown the method of connecting a loading coil in a telephone circuit.

The telephone repeater is another recent invention which gives great promise and in conjunction with loaded lines may increase the range of transmission of a circuit many times. A few of these repeaters are now in commercial operation.

There have been developed and placed in operation in a few cities so-called automatic telephone switchboards. How-

ever, in these systems the subscriber really does his own operating in that he is compelled to do the work of setting up figure combinations and operating keys, which in the manual system is left under the control of a skilled operator. These systems are marvels of mechanical and electrical ingenuity, but it is a serious question if they will ever come into universal use.

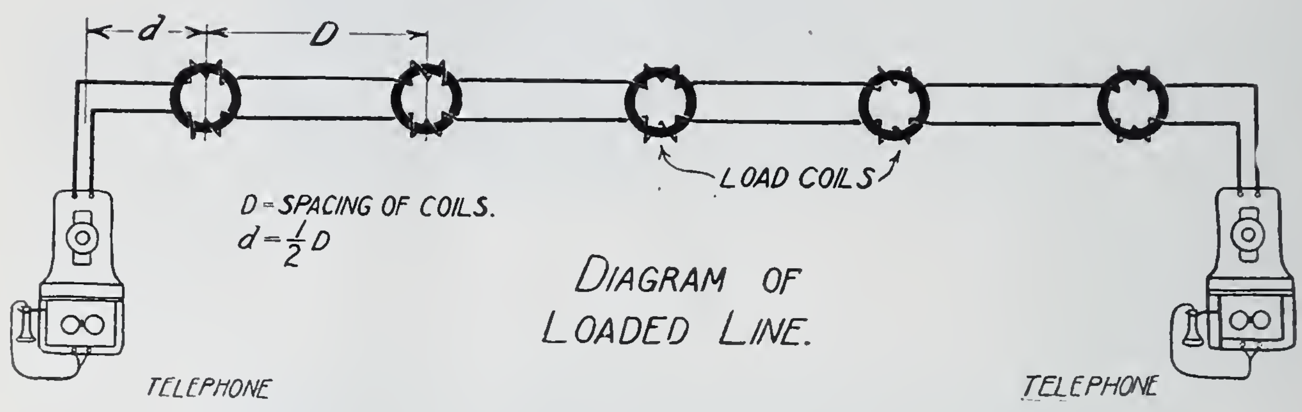


FIG. 16.

The present central battery switchboards are in reality full of automatic features. When a subscriber takes a receiver from the hook a lamp at central automatically lights; when the operator plugs into the line jack this lamp is automatically extinguished; when the called subscriber answers, a lamp on the keyboard shelf is automatically extinguished, and so on, through a multitude of automatic actions. It is probable that the development of telephone switchboards will be in the direction of still further supplying automatic devices to the present type of switchboard, thus increasing the efficiency and speed of the operator without eliminating the human brain from the connection and without causing the subscriber to do his own operating.

In bringing to a close this short paper on the development of telephony it is with admiration that I will touch briefly upon the very latest development in the art: wireless telephony.

The best work on wireless telephony has been done, I believe, by Professor R. A. Fessenden, a scientist of whom Pittsburgh has reason to be proud. He has developed a dy-

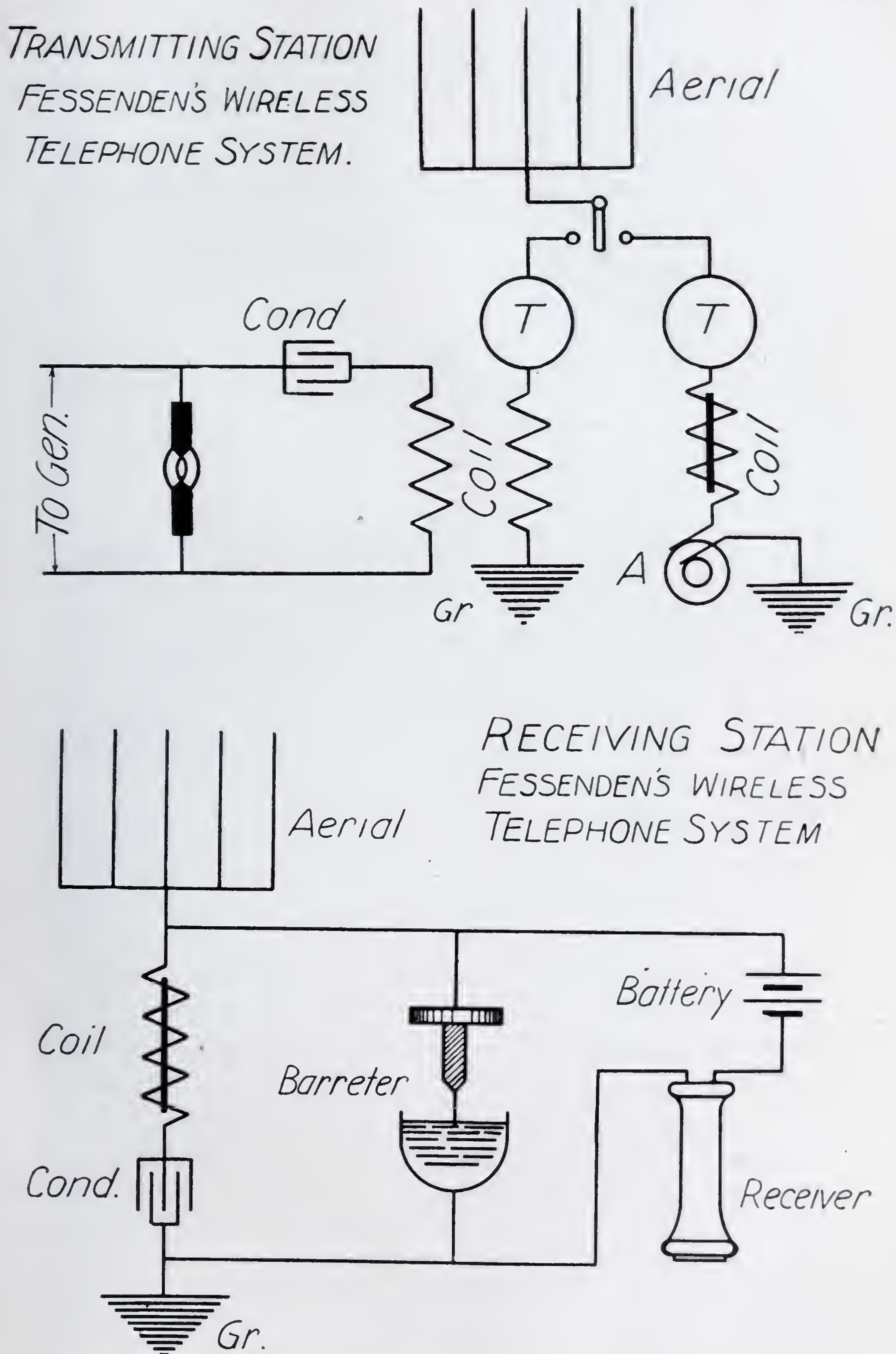

TRANSMITTING STATION
FESSENDEN'S WIRELESS
TELEPHONE SYSTEM.
Aerial
Cond
To Gen.
Coil
T
T
Coil
Gr
A
Gr.
RECEIVING STATION
FESSENDEN'S WIRELESS
TELEPHONE SYSTEM
Aerial
Battery
Coil
Barreter
Cond.
Receiver
Gr.

FIG. 17.

namo capable of producing electric currents at a frequency of 100,000 cycles per second, and at this high frequency electrical energy is radiated into space with ease. For the receiving station he has invented the liquid barretter, an instrument which is extremely sensitive to electric waves and which requires no decohering apparatus. In figure 17 is shown a diagram of Fessenden's system of wireless telephony. The stream of electric waves sent out from the transmitting station is varied by means of a transmitter located in the antennae circuit. The antennae at the receiving station conduct the electric waves through the barretter which changes its resistance in exact proportion to the amplitude of the incoming electric waves. A local circuit containing a battery and an ordinary telephone receiver will therefore reproduce the speech from the transmitting station. It might be added that the frequency of the electric waves is purposely made so high that there is no audible tone in the receiver. The receiver therefore responds only to the variations in the electric wave energy. It is too early to say what the commercial possibilities of wireless telephony may be, but it is probable that it will supplement instead of supplant wire telephony.

The growth of the telephone system in the United States during the past ten years has scarcely been paralled in any other line of business. To give you an idea of the magnitude of the business today the chart in figure 18 has been prepared, which shows the number of telephones connected to the Bell telephone system each year since 1876. The present number of telephones connected to the Bell system is about 4,000,000; the number of dollars invested in the business, 550,000,000; the number of miles of wire in use, 10,000,000; the number of telephone connections handled each year, 5,997,000,000.

Even in the face of the depression of the past year, the telephone business has shown steady gains, which clearly brings out the fact that the telephone is now in the necessity instead of the luxury class. It may be called the high speed tool of the 20th century which is shaping the business and social relations of the world.

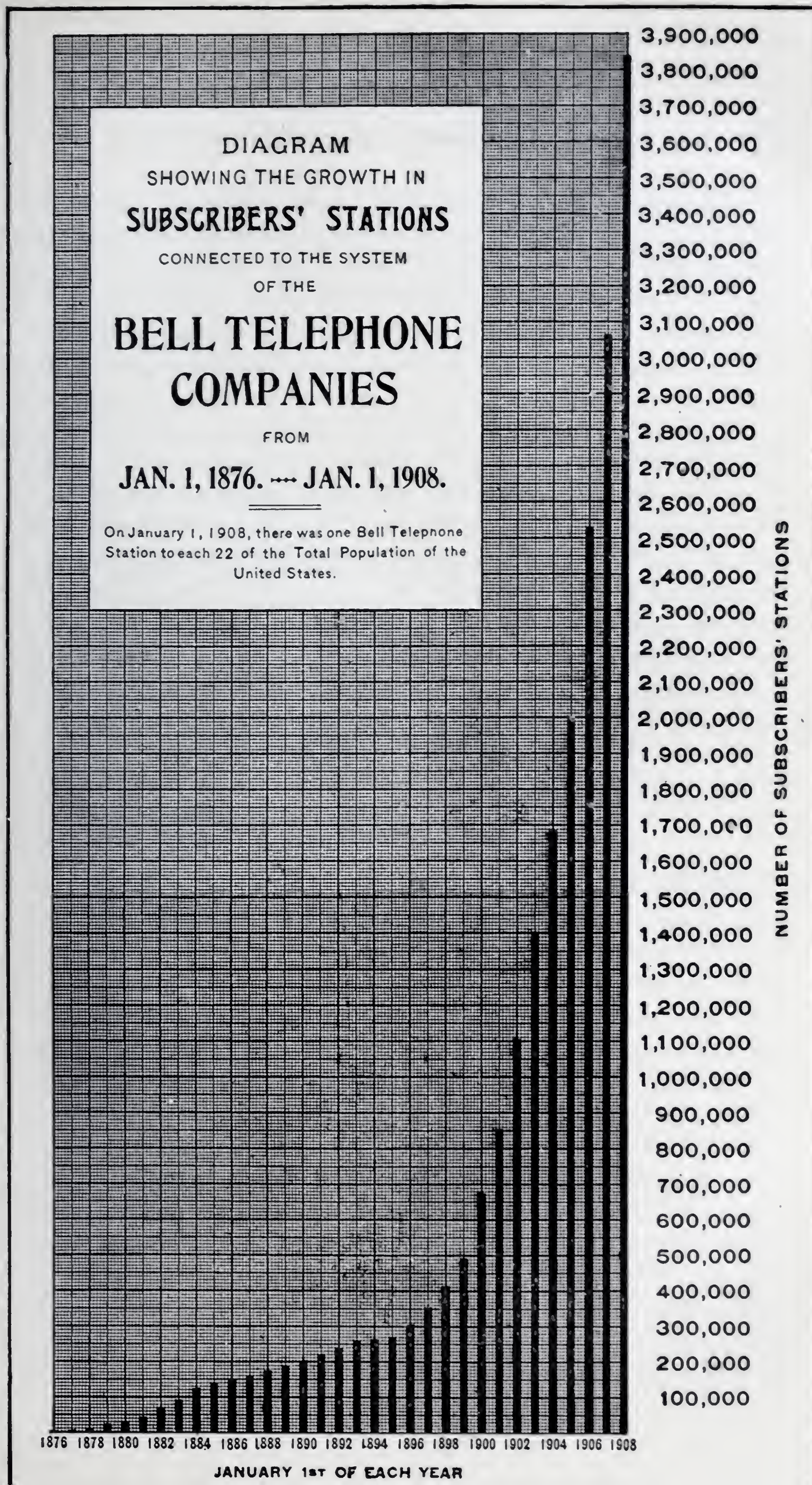


DIAGRAM
SHOWING THE GROWTH IN
SUBSCRIBERS' STATIONS
CONNECTED TO THE SYSTEM
OF THE
BELL TELEPHONE
COMPANIES
FROM
JAN. 1, 1876. — JAN. 1, 1908.
On January 1, 1908, there was one Bell Telepnone Station to each 22 of the Total Population of the United States.
3,900,000
3,800,000
3,700,000
3,600,000
3,500,000
3,400,000
3,300,000
3,200,000
3,100,000
3,000,000
2,900,000
2,800,000
2,700,000
2,600,000
2,500,000
2,400,000
2,300,000
2,200,000
2,100,000
2,000,000
1,900,000
1,800,000
1,700,000
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1,500,000
1,400,000
1,300,000
1,200,000
1,100,000
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
NUMBER OF SUBSCRIBERS' STATIONS
1876
1878
1880
1882
1884
1886
1888
1890
1892
1894
1896
1898
1900
1902
1904
1906
1908
JANUARY 1st OF EACH YEAR

The telephone companies are so industriously weaving their lines over the face of the country that soon it may come to pass that instead of a field of the cloth of gold, as in the time of Frances I., we will have a field of the cloth of copper, each thread of which is playing its part in the binding together of the thoughts, the hopes, the ideals, the fancies, and the ambitions, of the family, the state and the nation.

Perhaps in time to come the telephone lines of today may all be forgotten and Professor Ayrton's picture of the future be fulfilled. "The day will come, when we are all forgotten; when copper wires, gutta percha covers and iron bands are only to be found in museums, that a person who wishes to speak to a friend but does not know where he is, will call with an electrical voice which will be heard only by him who has a similarly tuned electric ear. He will cry, 'Where are you?' and the answer will sound in his ear, 'I am in the depth of a mine, on the summit of the Andes, or on the broad ocean.' Or perhaps no voice will reply, and he will know that his friend is dead."

DISCUSSION.

Mr. J. K. Lyons, (President): Gentlemen, I know you have been entertained by the paper on telephony and Mr. Grace's explanation of the subject, for I feel sure that many of us are not familiar with the numerous details connected with the construction and operation of the plant. If you have any question or discussion, the paper is now before you.

Mr. H. W. Fisher: After the reading of this excellent paper, one is filled with astonishment at the extent to which engineering is being introduced into telephone work. I can go back to the year 1891 or 1892 when Mr. Metzgar, the General Manager of Mr. Grace's company, asked me to call at his office, saying there was a fault in a telephone cable which he did not think could be located. Several people had tried to locate faults for them and had not been very successful. They had no one in particular to locate faults at that time, and those that had been located were by people who had come

from the Western Electric Company. I made measurements and located the fault over in Allegheny under a car track, and it was found only a few feet from where the measurements indicated it to be. This was simply a question of mathematics, and I bring it to your attention to show the great development that has taken place with the company in these years.

The fine work which has been done by the telephone company has caused persons in other lines supplying apparatus to the company, to scratch their heads trying to accomplsh unusually difficult things. It was only a few years ago that Mr. Grace came to the Standard Underground Cable Co. and said they wanted a cable in which the unbalance of capacity between two adjacent pairs would not be more than 1/100,000 of a micro-farad. We had to do a lot of experimenting before finally making a cable that would meet these requirements. This cable was required for use in connection with the Pupin coils mentioned by Mr. Grace. Not only the local company but other telephone companies have had to struggle with difficult engineering problems in order to get long distance transmission over the country.

Mr. R. A. L. Snyder: I first started to work for the Engineering Department of the Central District and Printing Telegraph Company in 1896. One of the first things to attract my attention was the non-uniformity of switchboards. We had to carry a large stock of the repair parts for each particular design, which made the maintenance very expensive, and special trunking circuits had to be designed whenever it was desired to run lines between offices. The Chief Engineer and myself talked over the situation and came to the conclusion that no fault should be imputed to our predecessors for installing such a collection of different boards, as the rapid advancement of the art had compelled it. However, the latest type of branch terminal boards being installed at that time was such a perfect piece of machinery that we believed the acme had been reached. We decided to stick to that form of standard, and all future boards

were to be uniform. We had great hopes of economizing, but they were blasted, as shortly afterwards we were informed that an improved board had been worked out, using one battery in the exchange to replace all the local subscriber batteries. After studying over this for a while we came to the conclusion that we would either have to adopt a new board or become a back number. Since that time new improvements have been coming along regularly and we have to adopt them for similar reasons. What the next improvement will be I am unable to say; perhaps a higher voltage board, but some change is sure to come making our present boards, costing hundreds of thousands of dollars apiece, old style, and putting our company to great expense to replace them, for we keep up-to-date on all improvements and try to furnish the people of Pittsburgh with the best service possible.

Mr. C. R. Rall: May I ask whether in the Fessenden system any receiving apparatus within the range of the waves can receive the messages, or whether they can be transmitted so that only one station can receive and others cannot get the messages.

The Author: The waves radiate into space in all directions and they can be picked up at any receiving station. It is possible to tune the receiving station and the transmitting station, so as not to cause interference with other receiving stations having a different tune. Prof. Fessenden has invented some very ingenious devices for securing non-interference, not very well known as yet, and he seems to think that he will be able to produce a wireless telephone apparatus which will permit the simultaneous handling of several thousands of connections without interference.

Mr. J. K. Lyons: There is one point which was not brought out in the paper and that is that the old style grounded circuit and Blake transmitter are entirely done away with.

The Author: Yes, they are no longer used. Practically all circuits are now metallic.

Mr. W. G. Wilkins: I read in one of the New York papers some weeks ago of a 16 year old boy who took his

father up on the roof of the hotel, with a little box about 12 in. square and telling him to listen, picked up some Fessenden wireless talk. Have you heard anything about that? This was a simple little box, with no wiring at all.

The Author: It is entirely possible. If he were very close to the transmitting station the waves would be so intense that with a very small area he would pick up enough to operate his apparatus.

Mr. E. B. Tuttle: That the end of developments in telephony is not yet becomes more apparent to the telephone engineer every day. When Prof. Pupin worked out a satisfactory practical loading scheme, it was found that reflection losses between loaded and non-loaded lines were very considerable, and a very expensive and complicated terminal tapering or gradual reduction of the loading at the ends was made use of to reduce the reflection loss. This was found very satisfactory from the operating standpoint, but was found too expensive for general use. Within the last year a specially designed transformer has been found to do this work and the work of repeating coil also, thus accomplishing the same saving from reflection losses with but very slight additional cost. The design of switchboards, although nearly as perfect as is conceivable from the present operative standpoint, will shortly give way to an entirely different type of board which will be more economical and more rapid. In the wireless telephone field of course there are very great possibilities for wide improvement, and, as Mr. Grace said, it will undoubtedly assist and supplement to a considerable extent the present wire long distance lines. So, as in all engineering work, we still look for, expect, and make an effort to design wide and far-reaching improvements in the art of telephony.

Mr. J. K. Martin: This is a little out of my line. My end of the business is mostly with the outside plant, that is the underground conduits, cables, terminal poles, etc., and the distribution of subscribers' wires from the office. It is a great field and one meets the public in different capacities, such as securing rights of way for trunk lines, block systems,

etc. I am not competent to speak after Mr. Grace and Mr. Snyder, who are experts, but if there are any questions in regard to the outside plant I will try to answer them.

Mr. L. C. Moore: Have you ever heard of glass poles for telephone purposes?

Mr. J. K. Martin: I never heard of glass poles. I have heard of concrete poles, and in fact I am having a few of them made at the present time.

The Author: I think glass poles have been used in Germany. The attempt was made to develop them a few years ago, but so far nothing has come of it.

Mr. R. S. Feicht: I believe Mr. Grace stated that speech has been transmitted as far as Denver. Is that the greatest distance it has been successfully transmitted in this country or abroad, and what are the prospects for transcontinental telephone service?

The Author: The gentleman misunderstood me slightly. I was very careful to say that our lines reached as far as Denver, not that we could talk that far. We give commercial service today up to about 1200 to 1300 miles. We know how to build a circuit to talk from New York to San Francisco, and we would do it with the aid of Pupin's loading coils and also the telephone repeater. It is a definite problem in electrical mathematics, and we can work out just what size of wire and how many loading coils will be required and where the latter should be placed. Without doubt, in the course of a few years we will have a line which will talk from New York to San Francisco, but at the present time the commercial returns would not warrant it. It is purely a commercial question. Regarding telephoning across the ocean, that is a little harder problem. In the first place the wire would necessarily be in a cable, and a cable attenuates the telephone current more rapidly than open wire line. In the second place the insulation would probably have to be gutta percha, which increases the capacity of the circuit very much above the ordinary paper cable. One of the principal reasons for using dry paper is the very small electrostatic

capacity of the cable. If a cable of that kind were insulated with rubber the electrostatic capacity would be several times greater and would therefore attenuate and distort speech a great deal more. In order to talk across the ocean we would have to put these loading coils in submarine cases and it would be a hard problem to get a case which would withstand the tremendous water pressure at the bottom of the ocean. We could talk across the water if we chose to use cables having large enough conductors, and if we could place these loading coils in submarine pots. It is a commercial problem. There is one other point that might be considered. The European business day does not coincide with ours and it would be rather inconvenient to call upon your broker in London and get him out of bed at 12 o'clock at night to place an order for shares of stock.

Mr. W. G. Wilkins: Is the paper insulation a rag paper or wood pulp?

Mr. J. K. Martin: It is supposed to be regular manilla paper, made from manilla rope.

Mr. R. A. L. Snyder: In connection with the question of transmission to Denver, Colo., one of our representatives was there during the Democratic National Convention and he informed us that Governor Hughes of New York was called up on "Long Distance" and was talked to from Denver. It has only been a short time since the Bell lines were put into Denver.

Mr. J. K. Lyons: Did they not talk from Boston to Galveston, Texas, a few years ago?

The Author: I do not think so. I myself have talked on a specially cleared line from Galveston, Texas, to Buffalo, N. Y., but we would not offer that service commercially.

Mr. L. C. Moore: To get back to the glass poles, I would like to ask the gentlemen what they would think of them if they could be made cheap enough commercially, as a substitute for the wooden pole. They are made hollow, 10¼ in. at the butt, 7½ in. at the top, 28 ft. high, and those I refer to were used in suburban service. There are some 200 of them

in use now, I believe, on the Imperial Post Line in Germany where they are experimenting with them. As near as I can judge they put the glass poles at the angles, where the wire took a sharp turn, and where the line ran straight there would be eight or ten wooden poles, and further on would be glass poles again. I understand they have been up one season, but they looked to me as though they would stand forever unless hit by a railroad train or something of that sort.

The Author: We would be glad to have any type of pole, whether of glass or anything else, which would in the end prove cheaper than our present type of wooden pole. If it can be shown that the glass pole is amply strong and in the end cheaper, we would be glad to use it. Our New York office has gone into the subject very carefully and have concluded to let the matter of glass poles rest for the time being. Creosoted wooden poles are the next step.

Mr. C. B. Albree: On the subject of wireless telephony, I am reminded of a lecture given by Prof. Kimball, now deceased, of the Worcester Polytechnic Institute, Mass., in 1883, to my class, in which he made the statement that it was possible to send messages long distances, even across the Atlantic, without the use of wires. He stated he could place a large generator, say in Maine, and connect it by an aerial wire to a ground in Florida. The current would then return through the ground, but would send out waves of electric energy in every direction from the ground point, and if between any two points in a radial line from the ground point, another aerial line were erected, connected at each end to a ground, it would pick up electrical current, due to the difference in potential, at different distances from the main ground, of the current returning to the generator; hence, any interruption of the main current would also occur in the picked up current and could be observed by suitable appliances, such as telegraphers use. So, if a ground were made in the Azores, and another in France, in a radial line from the main ground, messages sent over the American line could be received on the European line. This was certainly wireless telegraphy

as far as Europe and America were concerned. As a matter of fact, he stated that in Worcester, at that time, a burglar alarm establishment obtained all the current for its system from a wire between the office and the residence of the proprietor properly grounded at each end, the source of supply being from the main station of the Western Union Telegraph Co., in Worcester, and naturally, he got his current without cost to himself.

Mr. T. H. Johnson: Mr. Grace told us about the difficulties which we experience in the use of the telephone, that they were not always chargeable to the operators. He also showed us supervising lamps in front of the operators to advise them when the subscriber has hung up his receiver. I would like to ask him why it is we are cut off in the middle of a sentence sometimes. Does the lamp go out?

The Author: There are a great many contacts in the line and if any one is interrupted it will open the circuit and that will cut off speech.

Mr. J. K. Lyons: That can be done by another operator, can it not?

The Author: Yes, and it may be done by any one of the dozens of relays in the line, by a swinging line cross, or by short circuiting. There are so many thousands of chances of interruption that it is a surprise to me that we secure as good service as we do.

Mr. H. W. Fisher: I think the anomalies in engineering are very interesting. I remember a case where there was cable trouble, and one of the connections went into a store. The connections at the end of the cable were opened up and the trouble was located in the store. It was what you call a solid ground, the magneto rang strongly showing that the ground connection was good. We examined the wiring and there was nothing touching the wires until we came to the telephone. The telephone was on a wood panel and it seemed impossible to have a ground there of any kind. We opened the connection at the telephone and expected to find fault in the wire, but to our surprise it was in the telephone. Taking the telephone

down we found the boards back of it decayed on account of a leak from the roof, the water coming through the partition back of the paneling and there was no indication of moisture around the telephone.

Mr. R. S. Feicht: Referring to the location of a fault, if it can be located within 6 in., in a mile or two of cable how is the exact point determined? Are the cables mapped out so accurately that the exact length of cable to various points are known, or is it necessary to retest after the approximate locality of the fault is found?

The Author: The cables are very accurately mapped and we know the lengths. The first thing they do is to look for trouble in the splices. Most of the trouble occurs at the splices. If a fault occurs within 30 or 40 feet of a pole they ride in a little buggy over the cable and look for holes or other defects. As a rule they can spot it that way. If it is a case where there is internal trouble, by taking a short length of the cable they can locate it still more accurately. As a rule they are very successful in locating troubles of this nature.

Mr. Arnold Stucki: It was a long step forward in doing away with the ringing on a party line. It is a great comfort not to be roused out of bed at night by the call for some one else on the line. I do not see exactly how it is done.

The Author: We can place four telephones on one line and ring them in groups of two. That is two telephones are connected on one side of the line to the ground and the other two are connected with the other side to the ground. On a two party line there would be only one ring for each party. The signaling is done to ground and the operator can ring on one side to the ground for one subscriber, and on the other side for the other subscriber. If you do not want anybody on your line, we have a panacea for all that trouble which is very effective, and that is a single line.

Mr. F. P. Fisher: On a long line, say from Grant Exchange to a subscriber out in East Pittsburgh, can you still use the common battery or do you have to revert to the old local battery system?

The Author: In very long subscriber lines we use the central battery for signaling and place a local battery for transmission. As a rule we try to limit the length of these long subscriber lines, preferring to have them come into the nearest exchange, as this gives the best service.

Mr. J. K. Lyons: I understand the way you connect up the different centrals on the switchboard is comparatively new, where trunks run from one exchange to another direct. Two or three years ago the call might go through three or four exchanges to make the job complete.

The Author: As far as possible we try to have direct trunks between all exchanges, and the operator at the exchange where the call originated would give the order to the trunk operator at the distant exchange. The trunk operator at the distant exchange would not talk to the subscriber at all, but simply obeys instructions of the operator at the exchange where the call originated. We still have to trunk through one or more offices to some of our small exchanges, where there is not business enough to warrant direct trunks, but as rapidly as possible we are extending direct trunks. We now have about 65,000 telephones in use in Pittsburgh.

Mr. R. S. Feicht: In installing service lines in residences are the Underwriters' regulations followed? What provision is made to guard against damage which may result from lightning discharges or crosses with power or lightning lines?

The Author: We work in very close conjunction with the National Board of Fire Underwriters and attend their conventions every year. If you will refer to the National Code you will find a section on signaling wires in which it states how telegraph and telephone wires should be run into residences; and if you refer to our specifications for inside wiring you will note that we follow the Underwriters' rules. The line is extended from the pole to the house on insulators, and passing through the wall of the house the line runs through porcelain tubes. Then as soon as possible inside the house is placed a protector which is equipped with fuses and with lightning arrester. This lightning arrester consists of carbon

blocks separated by a perforated sheet of mica 5/1000 in. in thickness. These carbon arresters will break down with a difference of potential of about 400 volts, so that it will ground the line if it becomes crossed with a trolley circuit or any ordinary electric light or power wire. The grounding of the line makes a double ground at the protector and if a considerable current tends to flow the fuses will blow and open the line at the protector. Up to the protector we consider the telephone line as an exposed line and run it through porcelain tubes and on insulators to the protector. From the protector to the telephone is considered simply as inside wiring, like bell wiring, and is stapled in the ordinary manner.

Before the Structural Section, September 1, 1908.

Chairman E. W. Pittman
Presiding.

RENEWING FOUNDATION OF A WATER TANK.

By William Martin,
Member.

The water supply for the higher planes of the city in the vicinity of Blackhorse Hill, Pittsburgh, is furnished by two steel tanks, 40 ft. in diameter and 25 ft. high, each of 235,000 gal. capacity. One of the tanks rested on a concrete, the other on a timber, foundation. The latter had been in use about ten years, and in this period the timber became so badly decayed that its replacement was necessary.

The foundation was made up of layers of four inch pine plank laid transversely. The plank, we are informed, came from the Brilliant Oil Works, were thoroughly saturated with oil and for this reason it was believed they would be durable for the purpose intended. Decay soon became manifest, however, and at the time of renewal there was little sound timber found and no evidence existed that it had ever been impregnated with oil, the oil having completely evaporated, no traces of it remaining.

To remove the decayed timber and substitute a concrete foundation, it was necessary either to raise the tank high enough above the foundation for the necessary operations, or move it horizontally to a temporary site. The latter plan was adopted, as it gave free scope for operations. To do this an embankment was built, enclosing the existing and the temporary site of the tank, forming a pond. Posts were placed in the ground corresponding to the periphery of the tank and were also uniformly distributed to support the bottom.

These posts were all set at a given level and were high enough to give access to the bottom of the tank for painting as required by the City's contract. As stated there are two tanks in the system and when the one in question was in readiness to be moved, water was taken from the second tank, which was adjacent, to fill the pond. Having previously determined that eleven inches of water was required to float it, marks were made around the tank to indicate the theoretical draft. As the filling of the pond proceeded, the water rose four inches above the marks, causing alarm as to the accuracy of the calculation, for the water was getting near the top of the pond embankment; when suddenly the tank raised and settled exactly at the draft marks. The cause of the tank not floating at first at the calculated draft, was due to the decayed timber adhering so closely to the bottom of the tank, as to shut out the water from the bottom area, preventing the effect of the upward pressure of the water.

Previous to floating the tank the decayed timber foundation was pinned down with long drift-bolts driven through the timber, where any timber sound enough could be found, into the earth, to prevent the timber from floating until the tank was removed; but when the tank was moved about half its diameter the timber floated, tipping the tank and suspending operations until the timber was removed, the water in the meantime gradually seeped into the ground, settling the tank on terra-firma.

After removing the timber the pond was again filled, and the tank moved to its temporary site, settling on the posts referred to. The concrete foundation was built, the pond again filled, and the tank floated back to its original position. Bench marks were made before the tank was moved, so that in resetting the tank could be placed practically in its original location, and when in position it was found to be not over one quarter of an inch out in any direction.

The two tanks were connected by a pipe containing a shut off valve, so as to permit the use of one or both tanks at a time. The slight error of position in resetting, threw the

connecting pipe out of line and a new piece of pipe was substituted, but it would have been remarkable had the alignment been exact.

When all was in readiness previous to flotation, the bottom of the tank was well braced on the inside to prevent upward deflection; however, some arching of the bottom occurred. The necessary guylines and tackle for moving were gotten ready, and as soon as flotation occurred, it was moved from one site to the other, requiring about ten minutes in transit.

As a final operation to complete the work, the space between the bottom of the tank and the foundation was grouted in. Neat cement was used, as a grout with a mixture of sand would precipitate and not flow the distance from the center of the tank to the circumference. In pouring the grout, an indication of the complete filling of the space was a frothing all around the circumference of the tank, indicating that the void had been filled, thus making an everlasting foundation.

DISCUSSION.

Mr. W. C. Hawley: I would emphasize the necessity of properly filling the space between the bottom of the tank and the foundation, a matter which received little care until the failure of some tank bottoms drew attention to it. I had a case some years ago of the failure of the bottom in a stand pipe 10 ft. in diameter and about 132 ft. high. I was called out in the night, the report being that the stand pipe had burst. We were drenched before finally deciding that the water was coming out between the stones of the foundation, the top of which was about ten ft. above ground. After emptying the tank next day, examination showed that one of the wrought iron bottom plates had cracked along a seam immediately over the calking edge of the lower plate for a distance of some three or four feet. The crack was opened and it showed decided corrosion for a distance of probably seven feet. The stand pipe had been placed on its foundation with absolutely

nothing under it in the nature of a joint, and as it was filled and partially emptied three or four times each day, there had been considerable flexure of the upper plate over the edge of the lower one with the resultant breaking of the protective covering, and the plate ultimately rusted through. The tank was of such small diameter and relatively so high that we were afraid to leave it any longer than absolutely necessary, and not having the necessary tackle to guy it, a temporary expedient was used. We mixed some iron filings, sulphur and, I believe, chlorate of potash, giving the mixture about 24 hr. to set over the crack and then filled the stand pipe with water. Beyond a little leakage for a few hours, there was no difficulty and we kept it filled with water as usual, until we could get men there with new plates, bolts, etc., to make repairs. Upon cutting out that plate we found nearly 1½ in. of space beneath it and I have forgotten the number of barrels of cement poured under the plate before all the voids were filled. It would be interesting to know in the case of such a large tank as mentioned by the speaker, whether merely pouring from around the circumference would fill under the plates completely, or whether grout was poured through the plates from the inside. It would seem to me that the latter course might be necessary. The old practice usually followed in placing a stand pipe or tank was to lower it on a bed of mortar laid on the foundation; but it was difficult to get the tank in place before the mortar set. Sometimes merely a bed of sand was placed on the foundation and after lowering the tank cement was placed around the outside. I think the better method is to mix the sand and cement and place it dry, lowering the tank on that.

Mr. P. S. Whitman: I never have had any experience practically, but I understand that the best results are secured by using dry cement and setting the tank on top of it.

The Author: I neglected to state that we made four holes with riveted flanges in the bottom of the tank on a radius of 5 ft. from the center and screwed in 2 in. stand pipes, 5 ft. high, through which the liquid cement was poured

in rotation. The pressure from the stand pipes forced the grout to flow out to the circumference. An effervescence all around the circumference indicated that the grout had been forced the entire distance from the center, the air under the center of the tank escaping through the stand pipes. After the cement had set we went over the bottom and tapped it, a dull thud indicating that the voids had been completely filled. The holes for the stand pipes were afterwards plugged.

Mr. Morris Knowles: The paper describes a very neat process for doing a job which sometimes appears difficult, and I judge it had been thought out very carefully and that this was decidedly the cheaper method rather than using blocking and moving the tank in that way. If any estimates were made as to what the cost would be using blocking, including everything necessary, it would interest us very much to have the two compared. What was the date of the renewal?

The Author: We estimated that it would cost, including the dyke and everything, about one-half less than the blocking system. We had either to raise the tank high enough above the foundation for the necessary operations, or move it horizontally to a temporary site. The latter plan was adopted, which gave an unobstructed space on which to build the foundation, and an additional advantage in this plan was the use of water for flotation from the adjacent tank, which the city very kindly furnished. The foundation was renewed in the summer of 1905.

Mr. J. A. McEwen: Regarding the cost of the work, it would seem to me that the conditions would enter very largely into that feature of the question. If one had to build a dyke on a steep hill side and do a lot of grading it would probably be an expensive matter. I would like to ask the speaker if the timber was on the ground, or elevated, and whether the concrete foundation put in was an even bed or pillars.

The Author: The original timber foundation was right

on the ground and we built the new concrete foundation on lines radiating from the center about 3 ft. deep and on top of these walls laid a slab 6 in. thick and the tank was set on that.

Mr. V. R. Covell: The statement that this timber, though apparently saturated with oil at the time it was placed in position, was decayed and showed no trace of oil, raises the question as to the permanence of the impregnation in the creosoting process.

Mr. T. H. Johnson: What kind of oil was used?

The Author: Ordinary crude oil. I suppose the timber took a dry rot in there.

Mr. T. H. Johnson: Dry rot is not consistent with the theory of timber preservation. The theory is that the creosote or other preservative acts as an antiseptic to prevent the growth of fungi which constitutes decay. I do not see how it would be possible for dry rot to occur as long as the oil remains in the wood. I am puzzzled at the idea of the oil so completely evaporating as to produce decay in that length of time.

Mr. F. Z. Schellenberg: I do not know that I have anything to add, except that dry rot is a fungus growth, requiring some warmth for the continuance of its growth. I believe low forms of life cannot exist where conditions are such that the timber will not decay.

Mr. W. C. Hawley: Is not the explanation of this due to the fact that in preserving timber the creosote or other preservative is forced all through the wood under pressure, whereas merely soaking the timber in oil would not put it into the wood very far, and it would probably evaporate in a short time. Creosote does not evaporate. They use creosoted piling on the seashore to prevent the destruction of the piling by the teredo, and often in places where it is wet and dry between tides; yet the creosote remains and protects the wood.

Mr. W. M. Judd: Referring to the life of creosoted tim-

ber, I noticed in one of the engineering papers this week an account of some creosoted wood conduit, the product of the Wycoff Pipe & Creosoting Company, which was recently taken up in New York after being underground for 21 years and which was found to be in as good condition as when laid.

Mr. P. S. Whitman: The question of the thickness of the plates in the tank bottom, it seems to me, is one where there is a diversity of opinion. Some engineers use very thin plates, $\frac{3}{16}$ in. and $\frac{1}{4}$ in., the former being a little too thin for ordinary practice. I would like to ask those who have had experience what they would recommend in plates for a large stand pipe, say 50 ft. or 60 ft. The lower ring plates of the tank would be probably $\frac{1}{2}$ in. or heavier, and it is a question whether the bottom plates should be in keeping with the thickness of the lower rings or whether they should be light, say $\frac{1}{4}$ in. plates. The point I wish to bring up is that they are usually made thin. Is that a wise or economical thing to do in the end?

Mr. E. W. Pittman, (Chairman): It is customary to make them lighter; at least in all the stand pipes I have seen the bottom plates have always been much thinner than the lower rings. They have no stress to take and no special duty to perform except to retain the water. I do not see why it is not good practice, excepting of course, unless the plates are so thin that they would be apt to rust away quickly.

Mr. Richard Hirsch: I knew of a case some time ago where two firms were bidding on a stand pipe, and it had been customary previous to that time to erect stand pipes by scaffolding, necessitating figuring in the cost of the scaffolding, etc. The successful bidder secured the contract because he hit upon the plan of filling the tank as the work progressed and doing the work from a float inside the tank.

Mr. P. S. Whitman: It would still be necessary to have a scaffolding on the outside of the tank.

Mr. W. C. Hawley: Use a cage. I think the matter of floating up a scaffolding is a very common one. The difficulty is to properly protect the plates from rust while you are raising the scaffolding, that is to paint them and give time for the paint to dry. But it is a very common method.

Mr. V. R. Covell: What about the preservation of the plates? When a tank is filled more or less constantly with water, how frequently should the plates be cleaned and painted?

Mr. R. B. Woodworth: I have been making some investigations on the subject of painting with special reference to the corrosive effect of mine water on steel, as a means of ascertaining the best kind of protective coating to be used on installations of steel mine timbers. As you know, the mine water usually carries with it more or less free acid and its corrosive action is one of the reasons advanced why steel should not be used, and this in spite of the fact that an experience of fifteen years in the use of square timber sets of steel has proven that material can be very well protected from this corrosive action by the use of methods common in outdoor work.

Preliminary tests were made on small samples of tin painted with different kinds of pigment and subjected to the action of a ten per cent. solution of sulphuric acid. These preliminary tests indicated that the best paint for this purpose is red lead and oil. Of course, there are different kinds of red lead and different grades of linseed oil, and there is much liability of failure in these tests due to the lack of purity in the ingredients of which the paint is composed. The kind of paint which proved most satisfactory in these preliminary tests was about 25 lb. red lead to the gallon of natural linseed oil. I mean by that an oil which was not subjected to special treatment, but which was naturally of a good quality.

The next best results were obtained from natural red oxide of iron and the reason for the advantage of red lead, or the natural oxide of iron, for this particular purpose over either carbon paint or asphaltum paint, or some of the special

brands in which both lamp black and asphaltum are used as a base, is that the red lead and oxide of iron seem to have a better affinity for the steel and adhere more closely thereto than any of the carbon or hydro-carbon paints.

A very elaborate series of tests has been instituted at the instance of the Paint Manufacturers Association of America, under the supervision of committees E and U of the American Society for Testing Materials. These tests are to be carried out at Atlantic City. It is proposed to construct along the beach a fence made of plates 24 in. by 36 in. by 11 gauge, to be painted with fifty different pigments, but not including any special or patented paints. Two sets of plates will be used for each series of pigments; one set cleaned from rust and mill scale by a wire brush, the other set pickled and limed, and then painted with the particular grade of paint. In order that the effect of corrosion on each different class of material may be ascertained, each of these series of tests will be conducted on a different quality of material; first, on Bessemer steel sheets furnished by the American Sheet & Tin Plate Company; second, ingot iron sheets furnished by the American Rolling Mills Company; third, carbon Open Hearth steel sheets furnished by the Carnegie Steel Company. 150 sheets of each kind will be required for the proper completion of each test, and in addition to the effect of atmospheric conditions along the beach, a number of these plates will be subjected to the corrosive influence of sea water by suspension from one of the Atlantic City piers. The steel plates to be furnished by the Carnegie Steel Company will run from .15 to .20 carbon and will represent ordinary structural quality. The results of these tests should be of high value to the engineering profession and should be carefully watched by those members of our Society who are interested in protective coatings.

The preliminary tests referred to above will be continued probably along the theory followed in the painting of skeleton steel buildings, in which experience has indicated that the best results are obtained by first treating the steel to a coat

of red lead or oxide of iron, or some other mineral constituent which has the property of close adhesion to the steel, the second coat to consist of carbon or asphaltum paints, the idea being that the upper coat by its more perfect closeness of texture, prevents atmospheric action on the paint below. The whole subject is one of the most important under discussion at the present date, for the reason that the claims of the paint makers are widely conflicting and there is very little really accurate information to be obtained.

Mr. F. Z. Schellenberg: Is the carbon paint a hydrocarbon?

Mr. R. B. Woodworth: Yes, it is a by-product from the manufacture of coke.

Mr. E. W. Pittman: Mr. Johnson, did you not make some tests on paint recently in the interest of the railroad company?

Mr. T. H. Johnson: We did make some tests, but I cannot give you the results now, except in a general way. We found that the ready mixed paints are very uncertain materials. One experiment we are now trying may be of interest. There are certain portions of our line where salt drippings from refrigerator cars make it very difficult to keep paint on the floor beams and stringers of bridges. About a year ago began a test on these places with a paint made of coal tar and cement with a little coal oil used as a thinner. So far that gives evidence of resisting the action of the salt water better than anything we have tried.

Mr. Richard Hirsch: Probably Mr. Johnson could give us some of the results of his tests for publication in the Proceedings under the head of Engineering Data.

Mr. R. B. Woodworth: I would like to ask Mr. Johnson whether in his opinion the efficacy of his protective coating was not due more to the cement than to the tar.

Mr. T. H. Johnson: I cannot answer that positively, but I am inclined to think the cement is a prominent factor in the durability of it. I might mention another instance. At Columbus, Ohio, the viaduct crosses over the tracks with very

low head room, and we have had difficulty there in getting paint to withstand the smoke from the engines. The most successful thing we have used there is a combination of cement and linseed oil with red lead, mixed to the consistency of putty and applied with a trowel about ⅛ in. thick. That is standing well. A full account of this appeared in the "Engineering Record" July 18, 1908, p. 70.

Mr. F. Z. Schellenberg: I do not see how cement and linseed oil in a pigment could have anything to do with each other in the way of chemical affinity. We understand the hardening of paint pigment with linseed oil is due to resinification. It is the oxidation of linseed oil changing it to a resin that resists water and air. If an oxide is used, it will join directly with the oil for the reaction, e. g. red lead, which is an oxide of lead, and hematite which is the oxide of iron. I have seen iron oxide paint wrongly applied with petroleum oil which of course will not resinify.

Mr. W. C. Hawley: My experience is that oxide paint is an utter failure as a protective coating for steel or iron tanks that contain water. I remember opening a stand pipe for the purpose of examining it, and we found bushels of iron oxide paint and rust on the bottom and the plates were nearly bare. I never have seen the reason for using iron oxide to prevent steel or iron from oxidizing. If we could get a strictly anhydrous oxide it might be worth while, but we cannot, and if there is any that is hydrous, oxygen is carried to the plates and rusting and failure of the paint as a protection follows. There are a number of brands of asphalt and carbon paints on the market, that are very suitable for the purpose, and there are some creosote paints that seem to give very good results.

Mr. E. W. Pittman: How would iron oxide stand on the outside?

Mr. W. C. Hawley: Use it only for walls. It is all right, I believe, for use on wood, but it is not very satisfactory for steel or iron. The paint mentioned a moment ago was purchased under an engineer who certainly got the best of ma-

terials and it was mixed by a man who had been a painter by trade for years, and they supposed they had an unusually good job, but it did not pan out.

Mr. E. W. Pittman: The government has had so much trouble with keeping the lock gates painted in the two rivers here at Pittsburgh that they used nickel steel in the last two gates they put up, in order to avoid the corrosion, and I understand that even though the paint comes off, the nickel steel resists the action of the sulphuric acid in the water to such an extent that it practically does not deteriorate at all.

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President James K. Lyons,
In the Chair.

ELECTRICALLY OPERATED BRAKES FOR INDUSTRIAL PURPOSES.

By H. A. Steen,
Non-Member.

The successful operation of machinery, driven by an electric motor, is largely dependent upon the auxiliary apparatus such as controllers, safety devices and brakes. The design of these parts requires careful consideration, as they are called upon to do the most strenuous and responsible work. This has not been fully appreciated in the past, the neglect has caused a great deal of trouble and loss, and the fact that the controlling devices must be as carefully designed as any other part of the machinery, has forced recognition. As a result these appliances have undergone many changes in the last few years and manufacturers have spent a great deal of money in development work, which has brought out some satisfactory designs.

This also holds true for electrically operated brakes and this paper will place before you some typical modern designs, data for which has been recently obtained from manufacturers. These brakes serve to stop and hold the load and the moving parts of such machinery as cranes, hoists, elevators, conveyors and mill and shop machinery. They are required to absorb the kinetic energy, transforming it into heat, which is dissipated from the brake surface. They are generally called upon to brake for either direction of rotation and to produce an equal retarding effect in both cases. Only brakes of this description

will be considered in this paper. The design of an efficient electrically operated brake involves more difficulties than that of most other brakes on account of the high speed, the limited power and travel allowed for the electro-responsive operating device and the required compactness of the brake mechanism.

The brake must be simple, easily adjustable and constant in its action. The wear must be slow and not affect the braking power noticeably, and the worn parts must be easily replaced. The retarding torque should be uniform and bring the machinery to rest without shocks and blows, and powerful enough to insure accurate stopping. Upon the correct design of the brake, its careful manufacture and maintenance, depends in a large degree the satisfactory performance of the machinery with which it is employed. One manufacturer of cranes expresses this in his catalogue as follows: "The only part of our cranes, which require any special adjustment, are the brakes. If these are properly designed and adjusted our cranes will give entire satisfaction." The cost of the brake is small as compared with the total cost of the machinery and it does not pay to purchase a cheap brake if it is not the most satisfactory in every respect.

There are two classes of electrically operated brakes, one which employs weights and one which employs springs. The weights or springs apply the pressure to the wheel and the electro-responsive device generally releases the brake; a magnet is usually used for this purpose. If proper precautions are not taken the applied weight or the magnet plunger causes a blow on the wheel. This blow may exert a torque of many times the normal which in the case of a weight may be softened by using a dashpot. Where springs are used the magnet plunger should preferably be suspended, counteracting the spring pressure, and an overtravel of the plunger be arranged. This will prevent blows caused by the stored energy of the plunger. When springs are employed they should be placed so as to maintain practically an equal braking force without adjustment, until the wear has reached its maximum. Springs can now be made entirely safe and reliable if a rather low stress

is used, from 25 000 to 50 000 lb. per sq. in., depending upon diameter of wire and coil.

ELECTRO-RESPONSIVE DEVICES

The function of these in general is to keep the friction shoes away from the wheel. In some brakes, not often used, the pressure is applied by the electro-responsive device usually magnet; but these will not be considered. In brakes of the type described tonight, pressure is applied to the wheel when the current is "off" the motor and the magnet. When the controller is turned to its first position, its function is to apply current to the magnet, which releases the brake, and allows the motor to start up. The magnet opposes and overpowers the forces applying the brake. In this type of brakes the magnet is called upon to exert as much pull with the maximum, as with a closed, air gap.

The magnet plunger travels through a certain distance, closing the air gap between its stationary and moving parts, thereby separating the shoe from the wheel. As the brake surfaces wear the clearance between them becomes larger, the travel of the magnet plunger therefore increases with the wear and will at last reach a certain limit, when a still greater travel will not be practicable, on account of the weakening of the pull by D. C. and the increase of the current by A. C. magnets. An adjustment of the mechanism is therefore necessary to bring the plunger back to its initial, minimum, air gap. The allowable increase of the magnet travel should correspond to a fair amount of wear, about 1/32 in., so that adjustment should not be required too often.

Electro-responsive releasing devices may be divided into the following classes:

A — D. C. Magnets; a, Series; b, Shunt; c, Compound.
B — A. C. Magnets.
C — Turning armature magnets.
D — Motors.

A — D. C. Magnets; a, *Series Magnet*: This magnet is connected in series with the motor, and must be designed to hold the brake open with the minimum motor current. When called upon to release the brake it receives the heavy starting current of the motor at a time when it most needs it. After release has occured and the motor has started up, the current drops, but now only a small current is necessary to hold the brake on account of the closed air gap. The series magnet automatically applies the brake if the motor circuit should be accidently interrupted. The potential-difference across the terminals is very much less than the line voltage, rendering the insulation problem an easy one. This magnet has excellent characteristics as a releasing device and is the one most frequently used. In a few cases, where the armature current reverses or drops down to a very small value, it cannot be used.

b, *Shunt magnet*: This magnet is connected to the line in parallel with the motor and receives a constant current during the running periods, if a series resistance is not introduced at the end of its travel. The pull is therefore much larger than necessary with the closed air gap. Fig. 1, curve 1, shows the pull for different air gaps. The magnet must be insulated for more than the line voltage on account of the high tension induced by the field discharge when the current is broken. This high tension causes arcing on the contacts of the controller, which contacts have to be added when this type of magnet is used. The induced tension can be rendered harmless by connecting a field discharge resistance in parallel with the magnet coil. It also helps to prevent the magnet from closing the air gap. The shunt magnet requires some time for building up the field on account of its high induction. The action can be quickened by connecting a non-inductive resistance in series with it. By designing this magnet carefully its disadvantages may be minimized so that the introduction of the resistances mentioned would not be required.

c, *Compound magnet*: This has one series and one shunt

coil. The series coil helps to pull at the beginning of the stroke and quickens the action, the shunt coil helps the series coil to hold the magnet closed. The electrical effect of one coil upon the other when starting and stopping must be considered, when the magnet is designed.

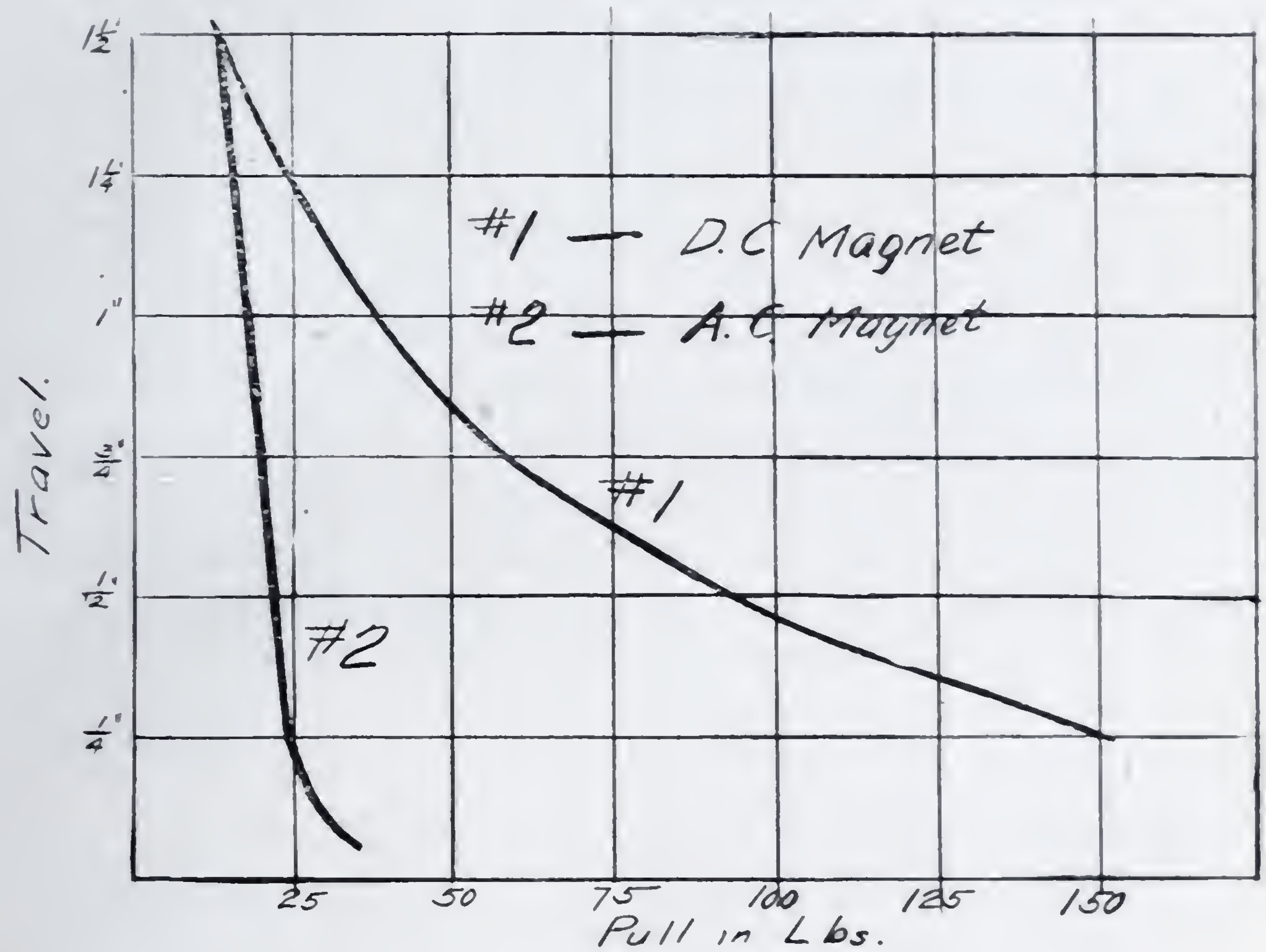


FIG. 1

The preferred type of D. C. Magnets is the "Iron Clad" where the coil is entirely surrounded and protected by iron or steel. As the magnetic resistance of steel is approximately one-half that of iron, considerable saving in size and weight is effected by its use. By corrugating the "housing" the radiating surface can be considerably increased. The plunger is of round steel, guided in the housing and often coned at one end to increase the pull in the beginning of the travel. This is of great advantage if a shunt coil is used. The coil should be insulated and treated with a vacuum impregnating and drying process, which practically converts copper and insulation into one solid mass, excluding moisture from the interior and

aiding in the dissipation of heat. The coil should be held in place so that it cannot turn or move axially. The lead wires from the shunt coil should be reinforced where they leave the coil, so that they cannot easily be torn off. There is generally an air space between the coil and the wall of the housing. The temperature may be kept lower by ventilating the housing or by introducing an insulating compound between the coil and housing which, however, would make it difficult to replace the coil.

B — A. C. MAGNETS: These magnets must be connected to the line in parallel with the motor, like the D. C. shunt magnet, on account of its high inductive resistance which would decrease the power-factor of the motor if connected in series with it. The current required by them is approximately proportional to the air gap, within practical limits, and drops to a very small value after the air gap is closed. The pull increases slowly with the decrease of air gap and nearly doubles upon closing. Fig. 1, curve 2, shows the performance of these magnets. The arc of the magnet current on the controller contacts gives little trouble.

The principal difficulty in designing an A. C. brake lies in the fact that the large starting current of both the magnet and motor appear simultaneously, taxing the line heavily, causing variations in voltage and disturbances in other circuits drawing power from the same system. It is therefore of great importance to keep this magnet as small as possible. If the magnet core should stick at its maximum air gap, the current would soon blow the fuses or burn the coils. But in this position the magnet makes considerable noise, which would draw the attention of the operator to the fact that the brake would not release, and the motor could not start.

Single or polyphase magnets are used. In the single phase magnet the pull fluctuates with the current and reaches maximum and zero values from 50 to 120 times a second, depending upon the frequency of the current. This condition causes vibrations and a humming noise, especially when the

magnet is closing. This can be lessened by placing a copper ring around one leg of the core in which a secondary current will be induced, which is out of phase with the main current. This induced current creates a field, which reaches its maximum and zero points at different times from the main flux and therefore does not permit the pull to decrease to zero. Two coils of different induction or capacity would effect the same result. The polyphase magnet is better in this respect as the two or more currents of different phase cause a more equal pull.

The A. C. magnet is built up of steel laminations to prevent eddy currents and the laminations are solidly riveted together. It is generally regarded as necessary to insulate bolts and rivets to prevent induced circuits, but if these are few in number and are located properly, this should not be necessary. One, two or three coils are used and the cores have one, two or three legs. This magnet can hardly be made iron clad, but may be covered with a non-magnetic metal case.

C — Turning Armature Magnets: These have been used with a Z-shaped armature. By shaping the armature properly the torque can be made constant or be made to vary to suit the releasing mechanism.

D — Motors: Motors are employed by a few manufacturers. They can in some cases be used to advantage especially for A. C. currents. The starting current does not reach the value required by an A. C. magnet. The motor is made to rotate a part of a revolution exerting its static torque holding the brake open. The action of a motor is, however, slower than that of a magnet. Some designers have proposed to use a magnet or a motor, in addition to the releasing device, for the purpose of varying the brake torque for different loads.

The kinetic energy, which the brake is called upon to con sume may be calculated as follows:

For kinetic energy of translative motion

E = kinetic energy in ft. lbs.
W = weight in lbs. of moving body.
V = velocity in ft. per min.
$E_1 = .000\,004\,32\, W\, V^2$

For kinetic energy of rotating body in ft. lbs.

W_2 = weight in lbs. of rotating body.
R_g = radius of gyration in inches.
R. P. M. = revolutions per minute.
$E_2 = .000\,001\,19\, W^2\, R_g^2\, (\text{R. P. M.})^2$
$E = E_1 + E_2$.
= total kinetic energy to be consumed and transformed into heat for one stop of the machinery.

The stored energy of the rotating parts E_2 is generally so much larger than E_1, that the latter can often be left out of consideration.

N = number of revolutions required to stop.

$$= \frac{.159\ E}{\text{torque}}$$

where the torque is expressed in ft. lbs.

As the friction of the machinery aids the braking action, the value of N as given by the formulae above is slightly too large.

T = time required to stop in seconds

$$= \frac{230\ E}{\text{R. P. M. x torque}}$$

The temperature rise of brake wheel and shoe may be calculated as follows:

H = total heat for one stop

$$= \frac{E}{778}\ \text{B. T. U.}$$

S = specific heat of iron.
= .1138.
P = weight in lbs. of iron heated.
R = coefficient of radiation
= .648 B. T. U. approx. (for 1 deg. F. rise per sq. ft. per hr.)
A = radiating surface in sq. ft.
t_1 = temperature rise for one stop

$$= \frac{E}{778 \times .1138 \times P}$$

$$= \frac{H}{.1138 \times P.}$$

An example will illustrate an approximate calculation:

$P = 10$ lbs. $E = 1456$ ft. lbs. $A = 1.1$ sq. ft.

$$H = \text{B. T. U. per stop} = \frac{1456}{778} = 1.87 \text{ B. T. U.}$$

$$t_1 = \frac{1.87}{.1138 \times 10} = 1.645 \text{ deg. F. for one stop}$$

and the heat dissipated for 200 deg. rise of temperature is

$$200 \times 1.1 \times .648 = 142.56 \text{ B. T. U. per hr.}$$

and the number of stops Y per hour for these conditions is

$$Y = \frac{142.56}{1.87}$$

$$= 76 \text{ approximately}$$

That is 76 stops per hour or one stop every 48 seconds may be made without a rise of more than 200 deg. F., which is entirely safe for iron. This calculation is only to be regarded as a fair approximation as many factors such as ventilation,

radiating surface, etc., cannot be accurately determined, but this gives a good idea of the heating conditions which may be expected.

FRICTION MATERIALS

The requirements for friction materials are a high and constant coefficient of friction, slow wearing qualities and rapid transmission of heat. The materials most frequently used are cast iron, steel, brass and bronze; and for linings and inserts maple, oak, ash, cotton wood, lignum vitae, fibre, cork and leather. The linings must be carefully selected, as they are often the cause of serious trouble, and their use should be avoided as far as possible. It has been the practice in the past to use linings for slow running brakes, which often were of large diameter, and this practice has been followed in the design of electric motor brakes. But here the speed is great and the diameter small, and the linings are subject to great strains, heating and wear. Where elastic linings or inserts like cork, are used, their unavoidable compression necessitates an additional magnet travel and renders the magnet more inefficient.

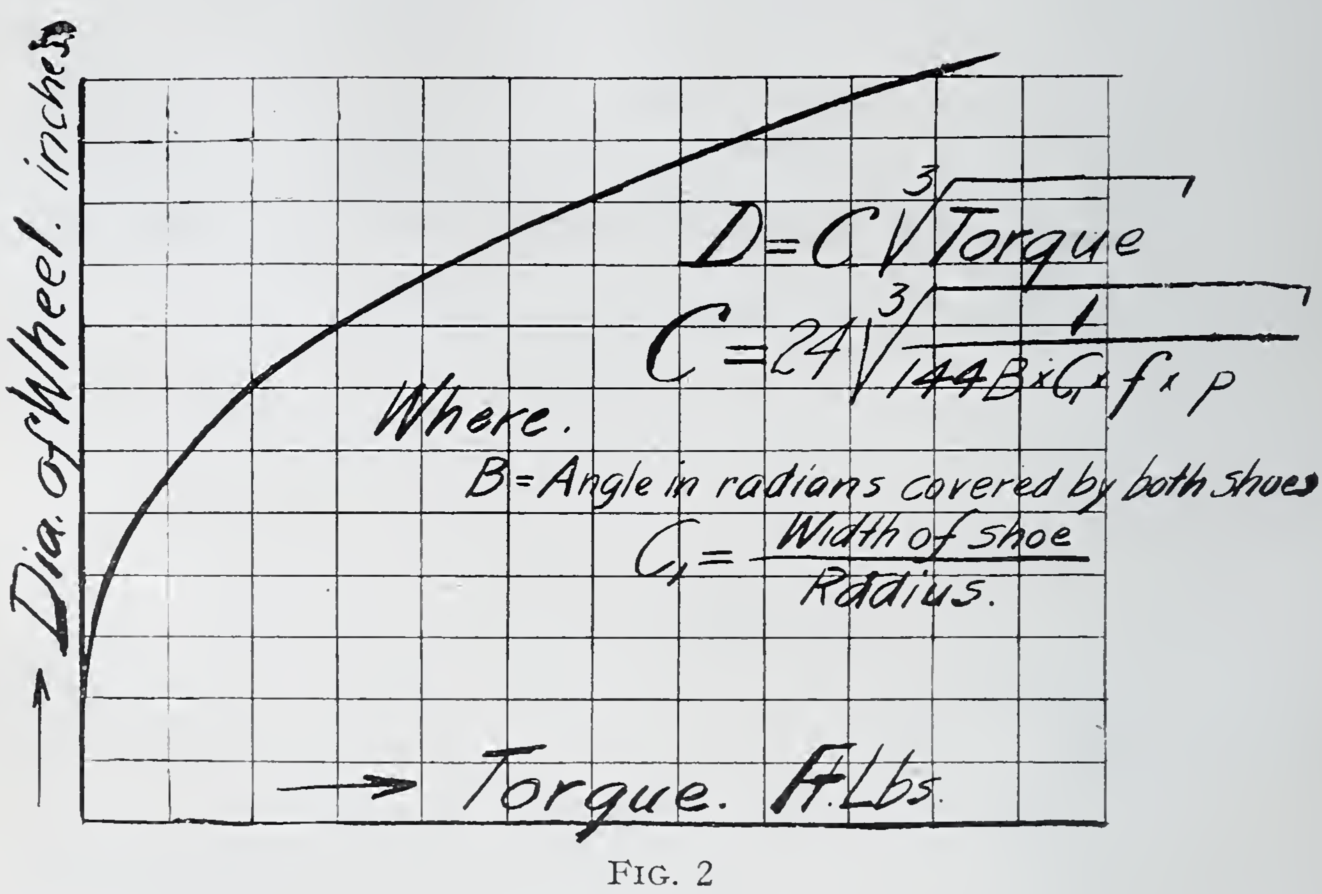


FIG. 2

Although treated wood is used successfully with some designs, it can safely be said, that a great deal of brake trouble is due to unsuitable linings and inserts as they keep the heat on the wheel and are liable to warp, crack, be torn off or burned. An experiment showed that one brake wheel heated about twice as much with a lining as without it, the shoe in this case absorbing and radiating but little of the heat.

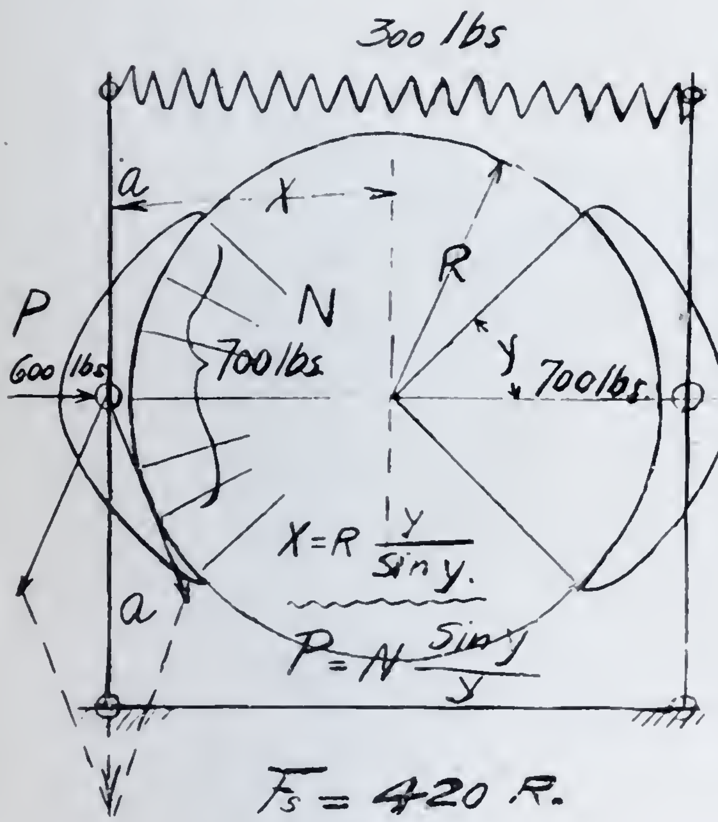


FIG. 3

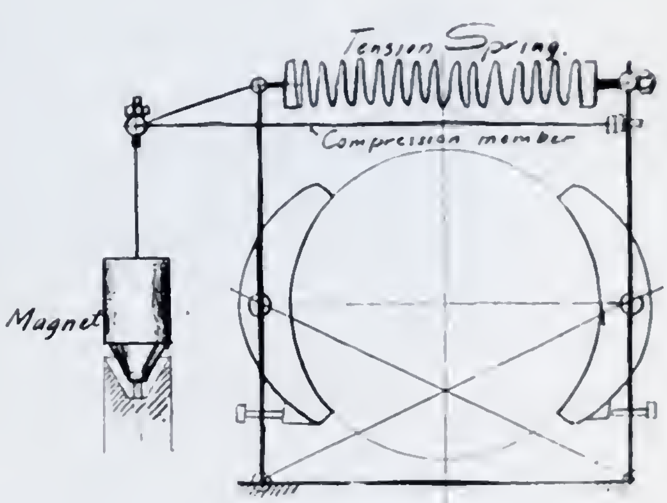


FIG. 4

One manufacturing company has gone very thoroughly into the question of the most suitable friction materials. The best results were obtained by using cast iron on cast iron, and this firm is now building both shoe and band brakes with cast iron as the friction material. Railroads use cast iron brake shoes and have found this to be the best material, and there is no reason why it should not be the best for electrically operated brakes. Bronze on cast iron is also good and is much used, especially for disc brakes.

The coefficient of friction of soft cast iron on cast iron has been found to average about .32. The coefficient varies with the pressure and speed but is not influenced by temperature within practical limits. Prof. R. A. Smart of Purdue

University, found the following results (Western Ry. Club Proceedings, Sept. 1900):

The coefficient of friction, f, decreases with increased pressure. A shoe of soft cast iron with 2000 lb. pressure showed f = .35; with 8300 lb. f = .22 at a peripheral speed of 50 mi. per hr.

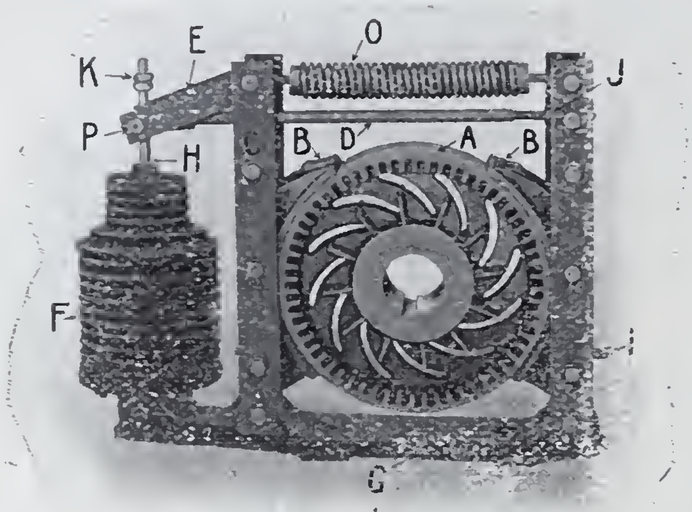


Fig. 5

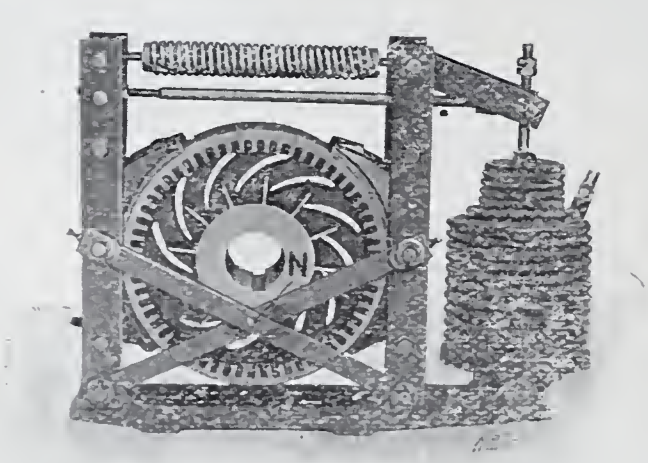


Fig. 6

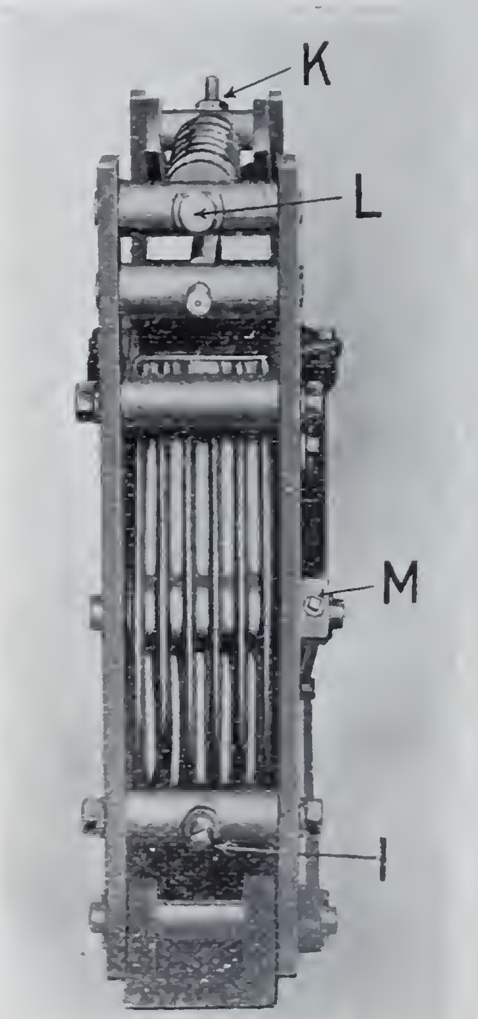


Fig. 7

The coefficient of friction decreased with increase of speed except from 10 to 20 miles per hour, between which it increases slightly. A shoe of soft cast iron with 7 000 lb. pressure showed f = .24 at 10 mi., f = .27 at 30 mi., and f = .18 at 70 mi. per hr.

Soft cast iron gives a higher coefficient of friction than hard cast iron. Experiments showed:

Soft cast iron at 2000 lb. pressure f = .35
Hard cast iron at 2000 lb. pressure f = .24

TYPES OF BRAKES

Apparently every individual designer of brakes has his own opinion concerning the most suitable construction, and this accounts for the numerous designs on the market. The arrangement of the mechanism and the electro-responsive releasing devices varies widely and is in many cases complicated and inefficient. Although a good brake can be made in different ways, there are some fundamental principles to guide the designer, which will be pointed out.

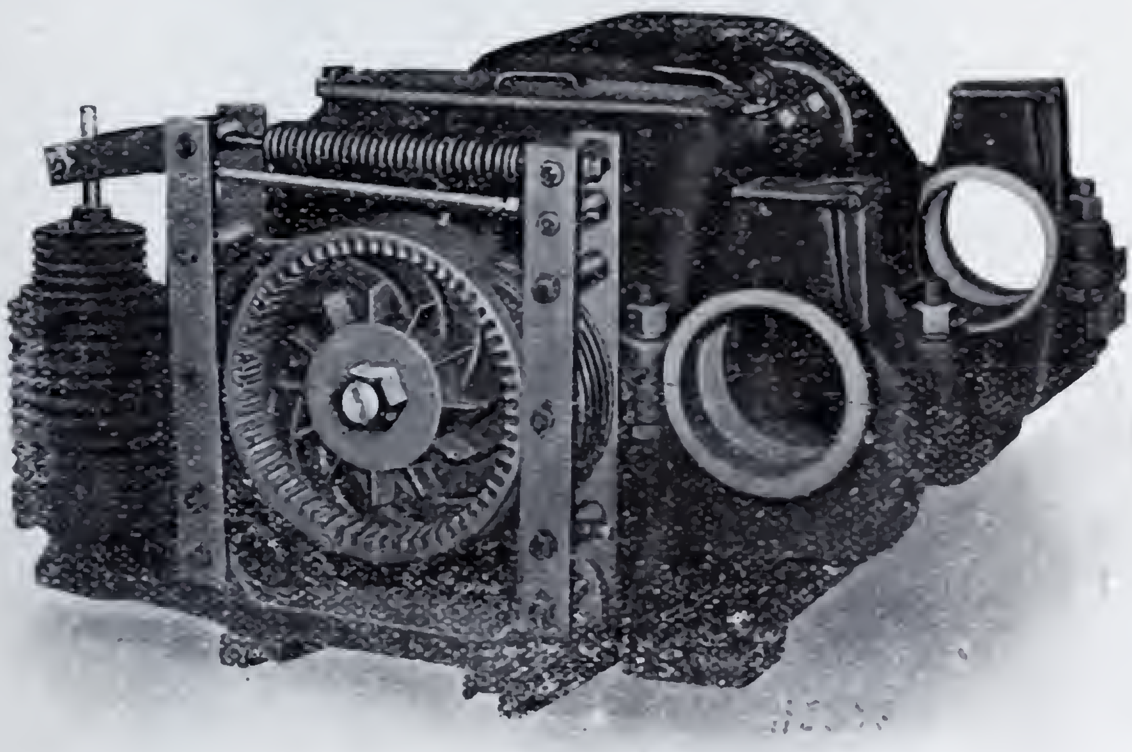


Fig. 8

Brakes may be divided into the following types:

A — Shoe Brakes
B — Band Brakes
C — Axially Applied Brakes.

A. — Shoe Brakes: If a line of shoe brakes is so proportioned, that the width of the wheel face varies directly with the radius, the pressure per square inch and the angle intercepted by the shoe are kept the same for all sizes, we find that the torque exerted is equal to the cube of the diameter multiplied by a constant which is dependent on the coefficient

of friction, the pressure per sq. in., the angle intercepted by the shoe and the proportion between the radius and the width of wheel face.

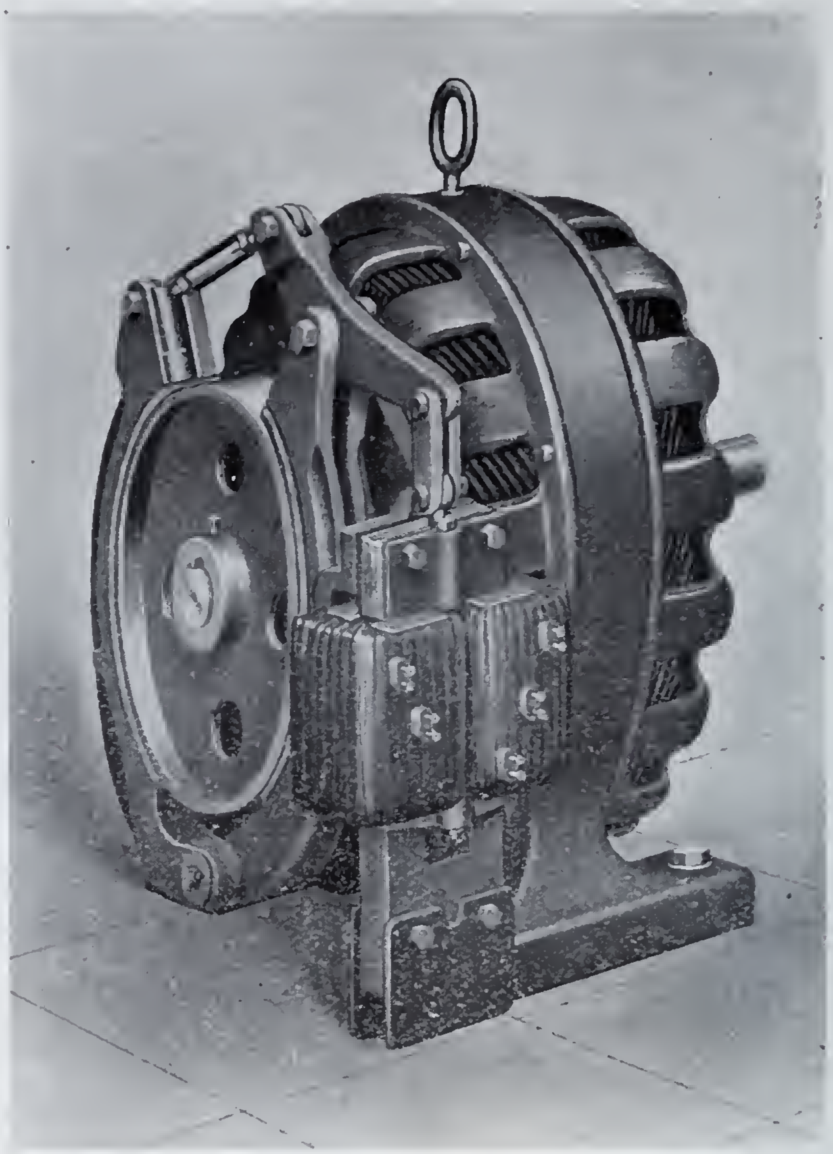


Fig. 9

In Fig. 2, these conditions are shown graphically and it is readily seen that the power of the brake increases rapidly with the diameter. The shoe may be pivoted or fastened to the brake lever. The fulcrum of the lever may be located on a line coincident with the direction of the braking force, causing compression in the lever, or it may be located inside or outside of that line causing a bending moment in the lever and unequal pressures on the two shoes.

If the shoe is pivoted on the lever, the pivot may be arranged in one of two ways. Either so as to cause wedging of the shoe, resulting in a heavier pressure at one end of the

shoe than the other, dependent upon direction of rotation; or it may be located so as to distribute the pressure evenly over the entire surface. The first arrangement often causes "digging" of the shoe and therefore rapid wear and noise. The shoe must separate evenly from the wheel. The wheel may have a straight face or contain one or more V shaped grooves. The grooves effect a higher pressure by wedging the shoe. In this case substitute for f,

$$f_g = \frac{f}{\sin\ \alpha\ + f \cos\ \alpha}$$

where α is one-half the angle included by the faces of the groove. For $\alpha = 30$ deg. 33% is gained, but the machining is more difficult and the required travel of the magnet greater. The wheel is, in some cases, ribbed and in one design is provided with vanes to promote cooling. The arms of the wheel should be curved to prevent excessive stresses caused by expansion, when the wheel is hot. The shoe may also be of the internal type, which in some cases gives a very compact arrangement.

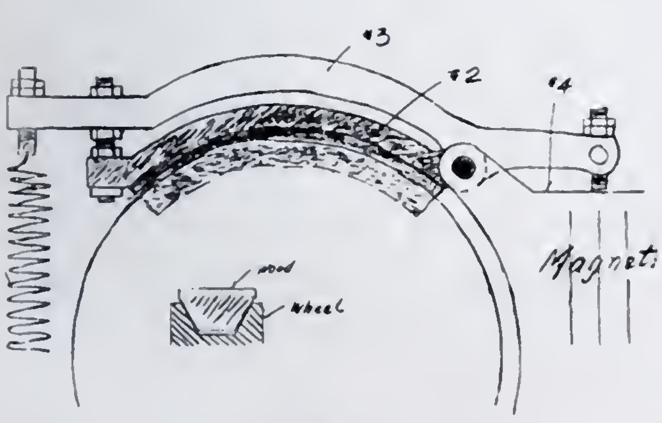


FIG. 10

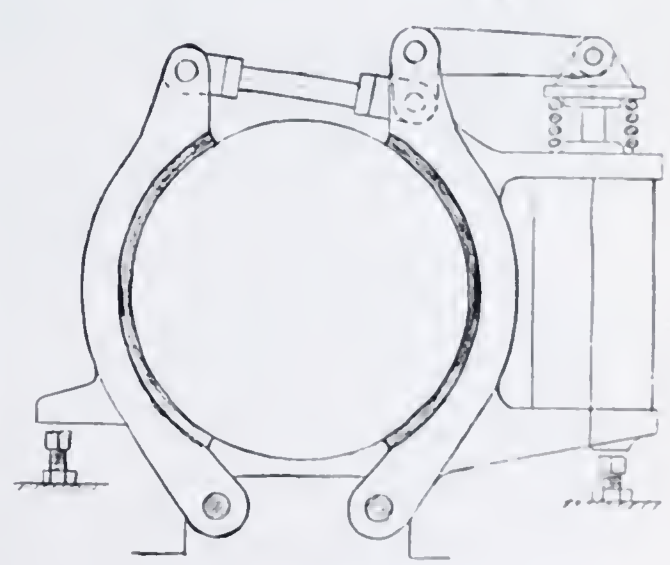


FIG. 11

Fig. 3 & 4 show a brake with the shoe pivoted on the lever so as to obtain equal pressures per square inch over the entire surface. All features concerning the correct arrangement of the magnet, spring, shoe and wheel previously pointed out in this paper are embodied in this brake. For more de-

tailed information concerning it see Mr. H. D. James' article in the Electric Club Journal of May, 1908, which describes a brake developed by Mr. James and Mr. W. A. Paris. This brake is more fully illustrated in Fig. 5 to 8.

In Fig. 9 is shown an alternating current brake, other types of shoe brakes are shown in Fig. 10 to 14. The construction of these can be readily seen from the diagrams.

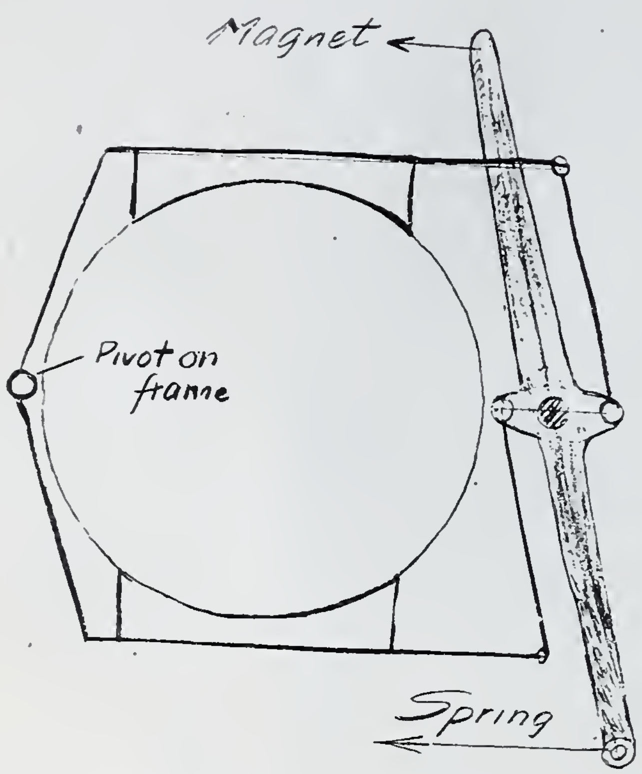


FIG. 12

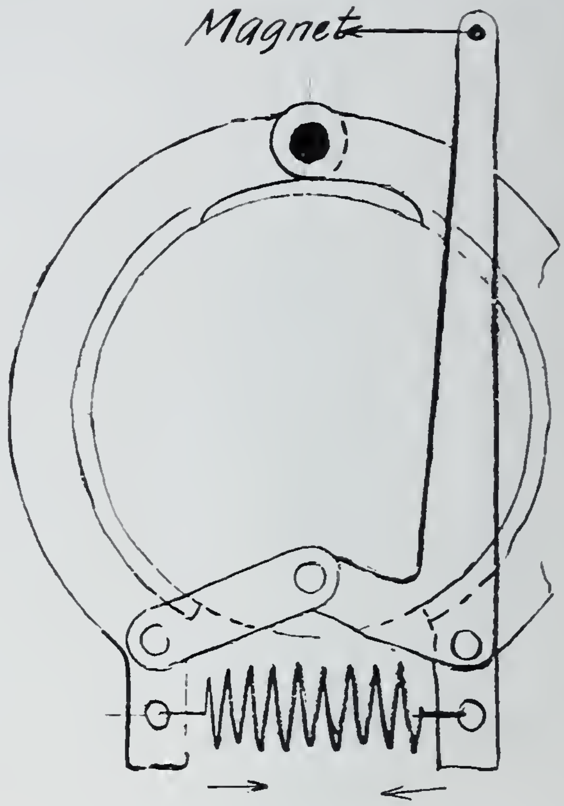


FIG. 13

BAND BRAKES

The design of an effective reversing band brake offers some difficult problems. Designers in the past have persistently failed to make this brake as efficient as the non-reversing band brake, being of the opinion that the force applied to the brake must overcome the retarding force in addition to the force applied to the other end of the band if equal effects for both directions of rotation are to be obtained. In spite of the imperfections of these designs they have been widely used. A reversible band brake, which is as efficient as the non-reversible band brake will find wide application, especially where it is of importance to make the magnet small and the entire brake light. Such a brake has been developed and will be

compared with other band brakes and also with the shoe brake in the following analysis:

A — A simple non-reversible band brake is shown in Fig. 15, in which

$$P_2 = P_1 \times e^{f\alpha}$$

as an example assume $e^{f\alpha} = 6$

then $P_2 = 6\,P_1$

where e = base of the natural system of logarithms

f = coefficient of friction

α = angle intercepted by brake band in radians

then for the retarding force F

$$F = P_2 - P_1 = P_1\,(e^{f\alpha} - 1)$$

$$F = 5P_1 \text{ or } P_1 = \frac{F}{5}$$

$$\text{then } K_1 = \frac{F}{5} \times \frac{a}{A}$$

where K_1 is the applied force.

B — A reversible band brake of well known type, is shown in Fig. 16.

With same values of P_1, P_2, F, a and A as above we have the applied force K_2 as follows:

$$K_2 \times A = 7\,P_1\,a$$

$$P_1 = \frac{F}{5}$$

$$K_2 = 7\,\frac{F}{5}\,\frac{a}{A}$$

Comparing the brake shown in Fig. 15, with brake shown in Fig. 16, it is seen that for the same braking effect, the applied force for the reversible band brake commonly in use is seven times that of the non-reversible.

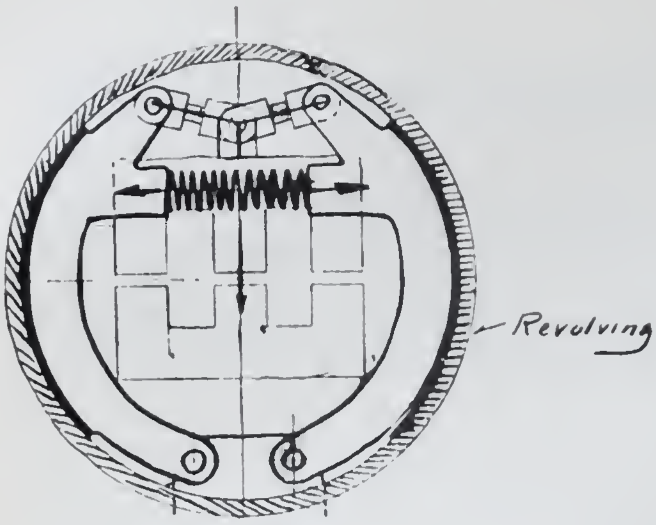


FIG. 14

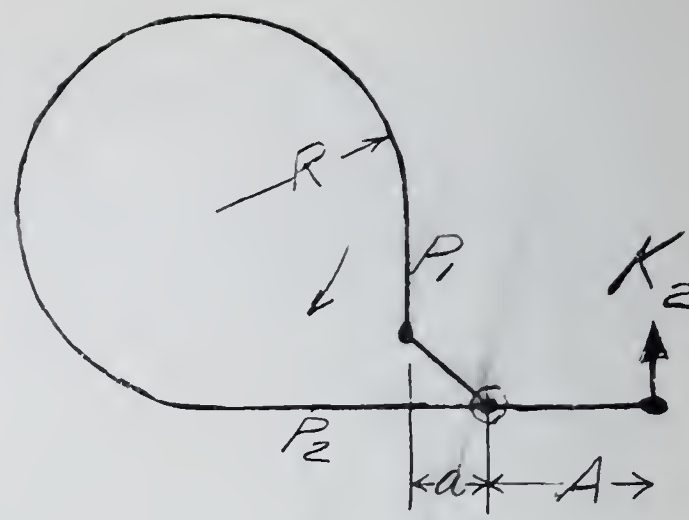


FIG. 15

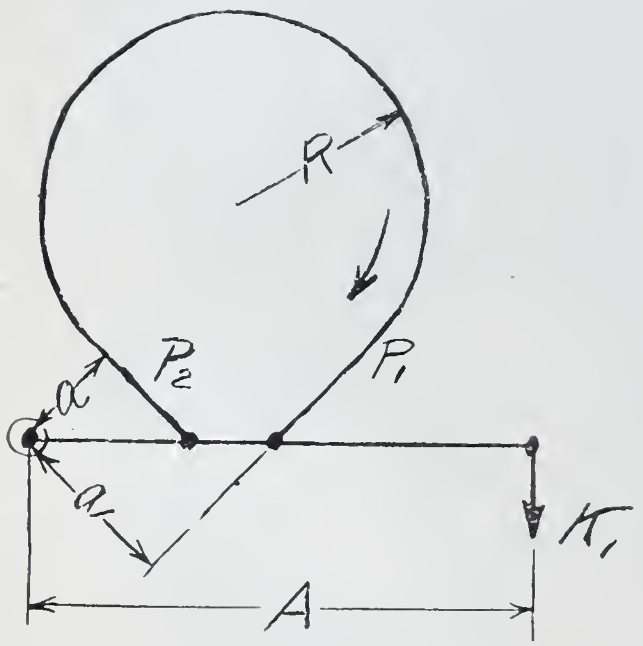


FIG. 16

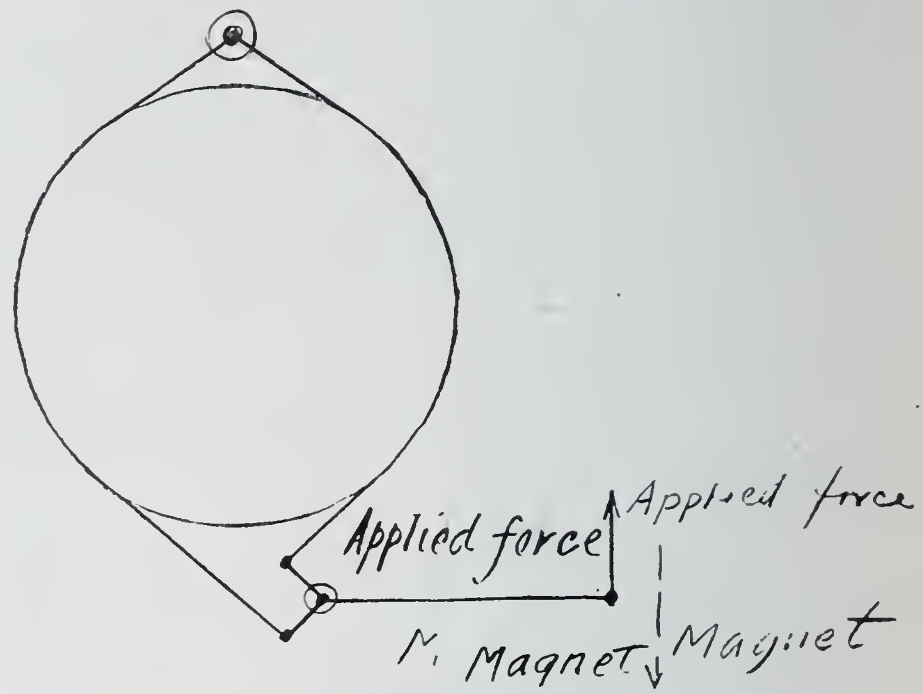


FIG. 17

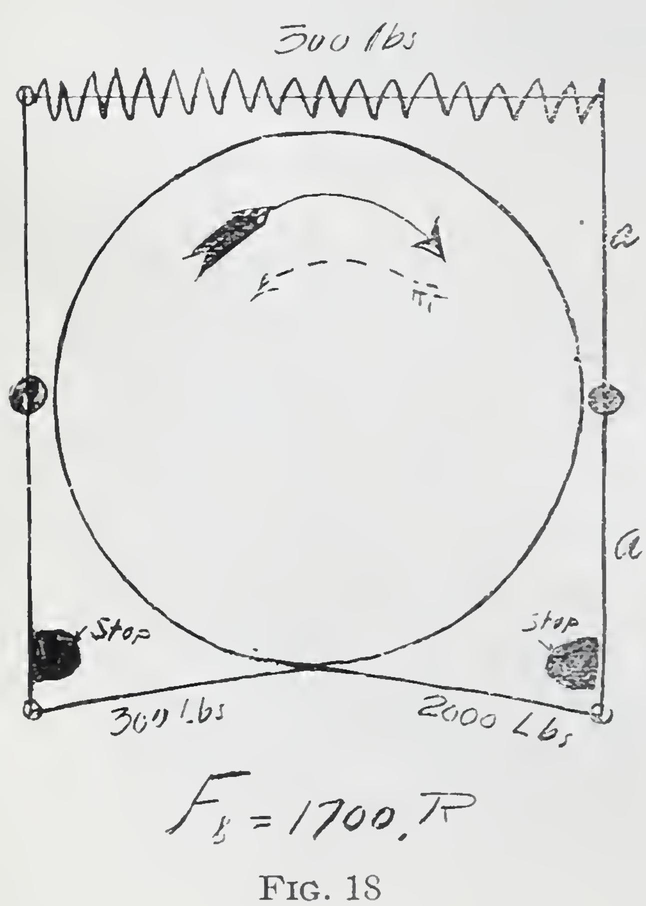


FIG. 18

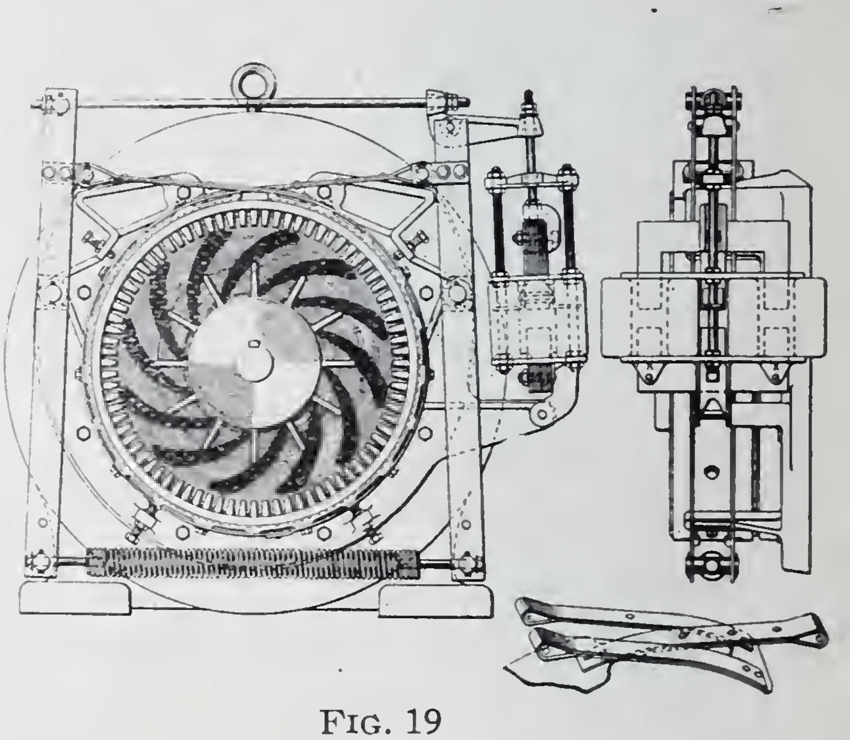


FIG. 19

C — Fig. 17 shows the diagram of another reversible band brake, where the band is made in two parts. Each part covers only a small angle and the benefit of the rapidly increasing accumulation of power by the larger angles is lost. One band is also much looser than the other, and the retarding force derived from this must be overcome by the force applied to the brake. This arrangement is therefore very inefficient.

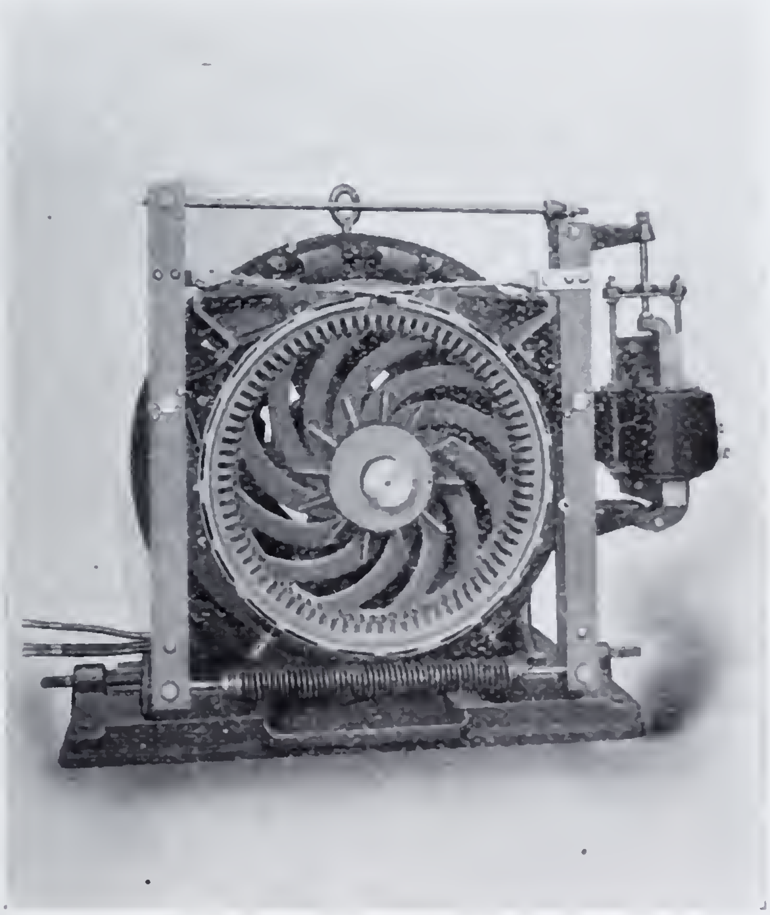


FIG. 20

D — Fig. 18 and 19 show the new improved reversible band brake mentioned above and Fig. 20 shows this brake mounted on a motor. This has the following advantages over other types:

a, The efficiency of this brake is a maximum and is as high as for the simple non-reversible brake.

b, The full benefit of the band principle is obtained by crossing the ends of the band and covering practically the whole circumference of the wheel.

c, The band proper consists of a cast iron cylinder, which is of slightly larger inside diameter than the wheel, therefore

separating easily from the wheel and maintaining an even clearance which may be adjusted by set screws around the circumference. A steel band wrapped around the cylinder receives the applied force, transmitting this to the cylinder and the accumulated retarding force to stops on the frame.

d, The mechanism is relieved of the high retarding strains, making the mechanism exceptionally light.

e, The brake requires a very small magnet. In one case, a 65 lb. magnet was required for a brake of 2000 lb. retarding force on a radius of one foot, a result not approached by any other design. This brake is therefore especially applicable to A. C. motors, where the magnet current must be kept low. This form of brake is light, simple and effective and has given excellent results.

It is of interest to compare this brake with a shoe brake. Fig. 3 shows a shoe brake where the retarding force is

$$F'_s = 1400 \times .3 \text{ R} = 420 \text{ R}$$

where 1400 is the total pressure in lb. applied to wheel surface.

.3 is the coefficient of friction.

R is radius of wheel.

Fig. 18 shows a band brake where the retarding force is

$$F_b = (2000 - 300) \text{ R} = 1700 \text{ R}.$$

where 300 is the pull in lb. applied to one end of band, 2000 is the accumulated tension in the other end of band, due to rotation of wheel.

It will be noted that this improved band brake exerts approximately four times as great a retarding force as the shoe brake. The magnet is therefore only one quarter of the size required by the shoe brake for the same retarding effect. The curves in Fig. 21 show clearly the relation between the braking moment and the angle intercepted by the band for three different coefficients of friction. For any other applied force, P, and radius of wheel, R, multiply the values of the unit retarding moment, m, by P and R for the total retarding moment M. Curve 2 shows an increase of approximately 100% in the re-

$$F = P\cdot(e^{f\alpha} - 1) \quad , P = 1$$

$$m = (e^{f\alpha} - 1)\cdot r \quad , r = 1$$

$$m = e^{f\alpha} - 1$$

$$M = (e^{f\alpha} - 1) \times \mathbf{P} \times R.$$

$e^{f\alpha} - 1$ is plotted:

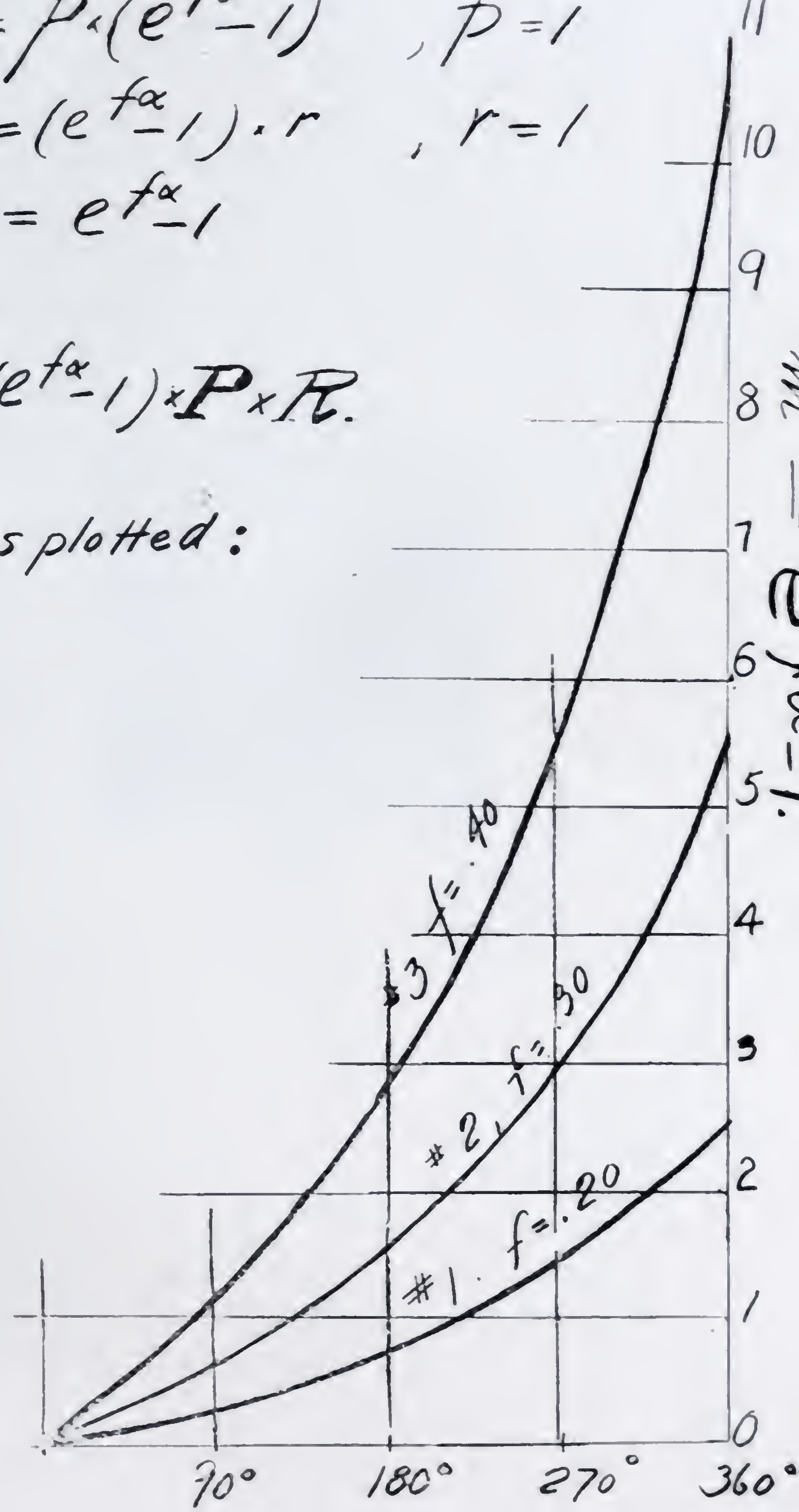


Fig. 21

tarding moment for the last 90 deg. of the circle. This emphasizes the importance of intercepting as many degrees as possible. The power of this brake, like the shoe brake, increases rapidly with the diameter.

AXIALLY APPLIED BRAKES

In this class of brakes the spring or springs and the magnet are placed around the shaft exerting pressure in an axial direction. The release magnet is somewhat stronger than the springs and the travel of the magnet is very small, varying from 1/16 in. to 3/16 in. This brake can easily be made dust proof or oil tight. There are two principal types of these brakes, the disc and the conical brake.

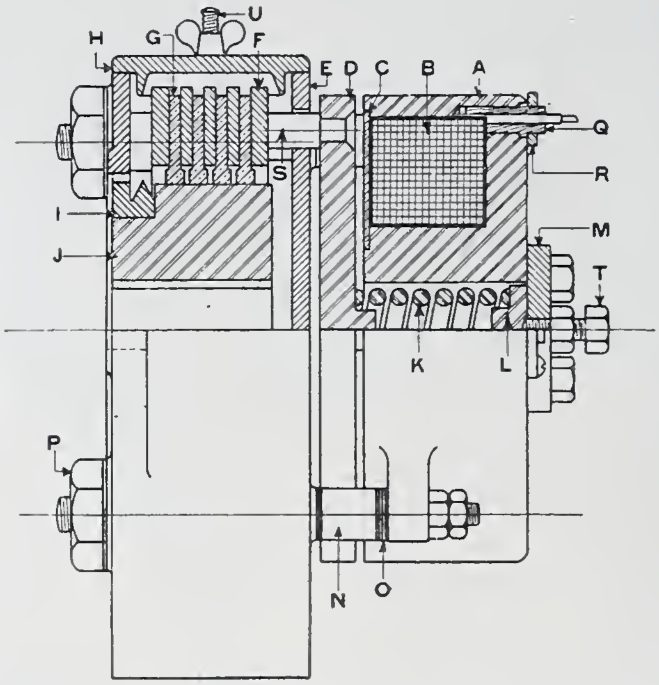


FIG. 22

Disc brakes are based on the well known Weston principle, described as early as 1868 in the Proceedings of the Institute of Mechanical Engineers. One stationary and one revolving set of disc plates are used. The stationary plates may be attached to the frame by bolts, or they may be made square and fitted into the frame. The revolving plates are keyed to the shaft and interleave between the stationary plates. All the plates are free to move axially and to separate when the spring pressure is relieved by the magnet. The spring pressure is applied to the first stationary plate and transmitted through all the plates. The reaction is taken up by the frame.

The retarding force is proportional to the number of surfaces in engagement. The "multiple" disc brake generally runs in oil, which has an effective cooling quality, keeps the plates from cutting and the coefficient of friction more constant. The stationary plates are of cast iron, the revolving ones of bronze or semi-steel. The stationary plates are in one make, provided with cork inserts forced into drilled holes. The value of the cork is said to lie not so much in its frictional qualities as in its ability to keep the plates clean and to act as wicks for lubricating the surfaces.

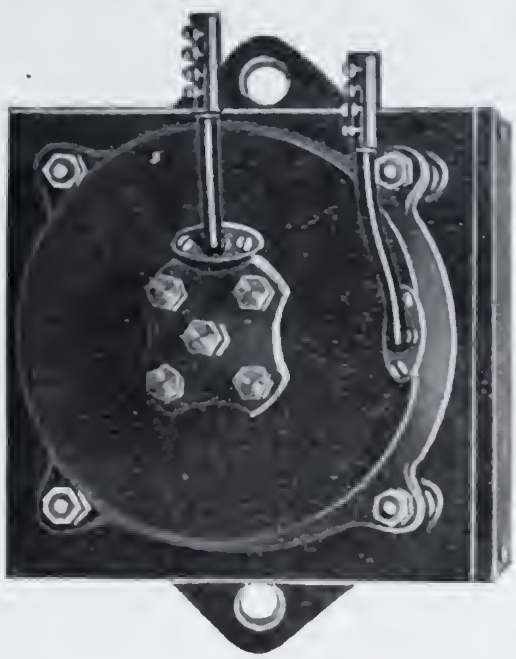


FIG. 23

The wear is taken up by adjusting the position of the magnet, which is bolted to the frame, or a new stationary plate may be inserted when the total amount of wear equals the thickness of one plate. The spring is adjusted by screws. When it is necessary for the shaft to be extended through the brake, the central spring is replaced by four springs at the circumference of the magnet armature plate. In Fig. 22 is shown a section of a multiple disc brake and Fig. 23 is an outside view of same. Fig. 24 shows the brake mounted on a motor. In some brakes only one disc, keyed to the shaft is used. The armature and shaft of the motor are allowed to move axially approximately 1/16 in. and the disc is, when in braking action, pressed between the magnet disc and the brake frame. Wooden inserts in the rotating disc or in the station-

ary brake surfaces are frequently used in this type, the grain of the wood running perpendicularly to the surfaces. Fig. 25 shows a brake of the single disc type with wooden inserts in the rotating disc.

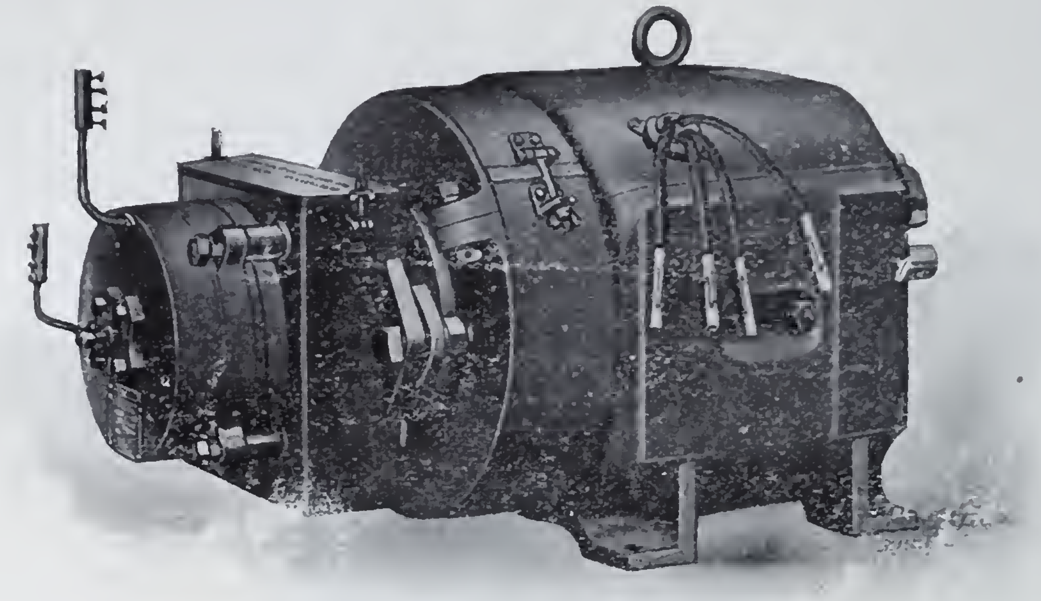


FIG. 24

The conical type consists of one stationary and one rotating friction member with conically shaped friction surfaces. The pressure is increased by the wedging action. Single or double cone shaped surfaces are used and linings are employed in most cases. One brake of this type has cylindrical wooden inserts in the rotating cone, held in position by a cast ring and bolts. No holes are drilled in the wood. The ends of the several pieces are cut to form part of the conical surface. These wooden inserts are machined and when worn can be easily replaced by new ones of exact size.

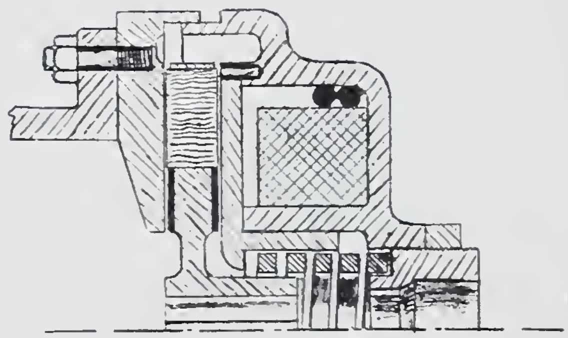


FIG. 25

Some difficulties will be encountered in attempting to operate axially applied brakes with alternating current, where a laminated magnetic circuit is required.

This paper will be discussed at a meeting to be announced later. Members of the Society and other readers are requested to prepare discussion which may be mailed to the Secretary if desired.

REGULAR MEETING,

October 20th, 1908.

President James K. Lyons

In the Chair.

THE EFFECT OF WIND ON HEATING AND VENTILATION.

By H. W. Whitten,

Non-Member.

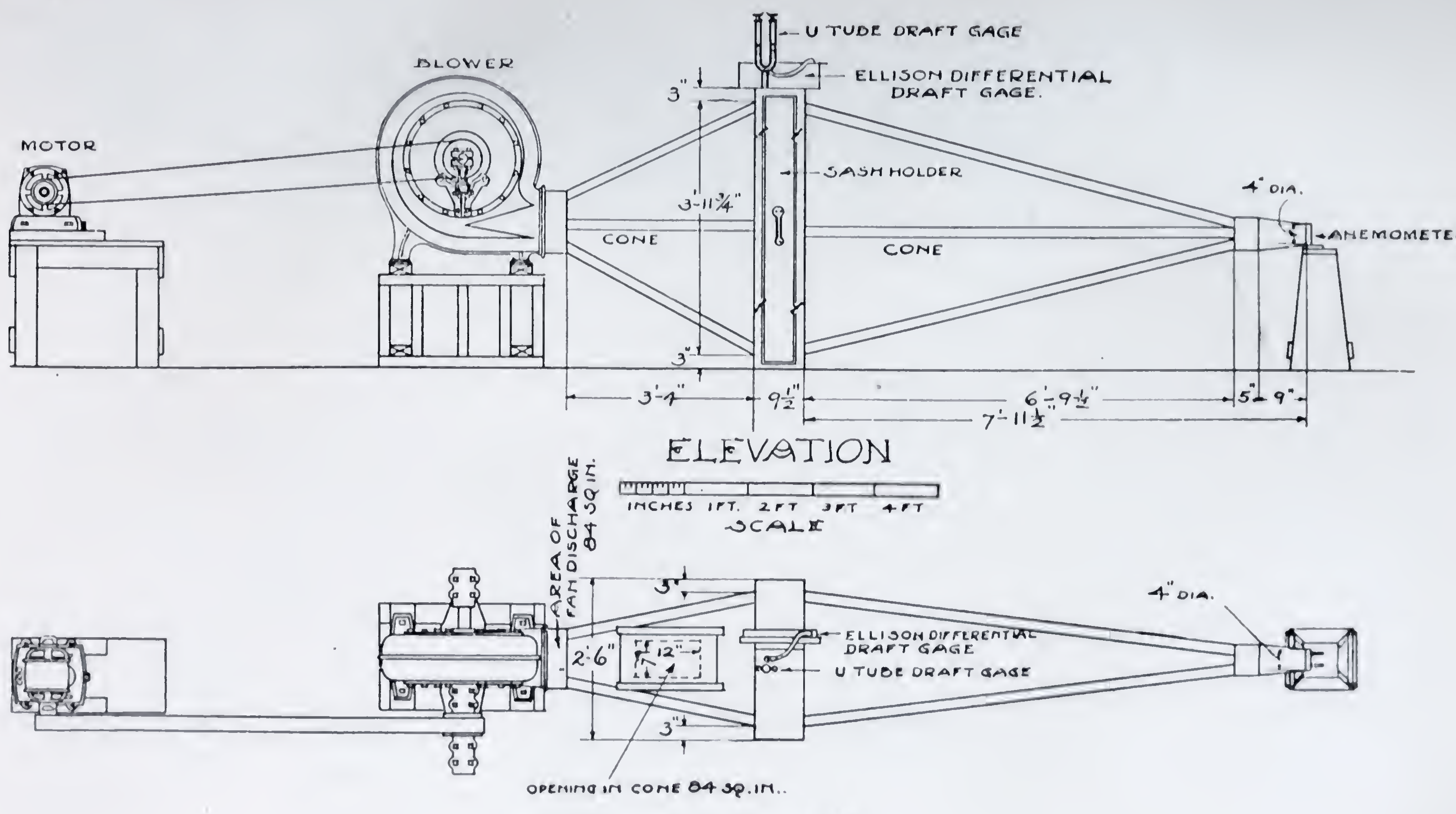
Heat having been generated and circulated through a building, it is of economic importance to find out what becomes of it, i. e., to trace its dissipation. It is lost in three ways, by passage through foul air flues, chimneys, etc., by direct transmission through walls and windows, and by filtration through walls and air leakage through crevices around windows and doors. The first two losses are easily determined, but to quote the latest book on the subject by Prof. John R. Allen of the University of Michigan, "The calculation of loss by filtration and leakage must always involve a large factor of judgment and experience." In other words the engineer must *guess* at it. This same unsatisfactory and elusive statement was embodied in a report of a committee at the annual meeting of the American Society of Heating and Ventilating Engineers in New York, January 21, 1908.

One factor which has been known abroad for sometime but generally overlooked here, is that all buildings are more or less porous. Probably most of you are familiar with the "Brick and Candle" experiment, but I have seen two bricks placed end to end, joined with mortar, wrapped tightly with impervious material, excepting a space ½ in. in diameter at each exposed end used for this same experiment. One space was covered with soft soap, and by blowing against the opposite end bubbles could be raised in the soap. A very safe statement is that in a well constructed building, with all doors and

windows tightly closed, the air will change about once in an hour. One reason for this is not generally recognized. *Air is constantly seeking its own level.* As it is heated it expands, and at once attempts to rise to a height where it will find air of a similar density, the colder air rushing in underneath to fill the space vacated. It will, when heated, follow the line of least resistance in order to finally rise. It thus seeks out any porosity in the building, and escapes through it.

Leakage by means of crevices about windows and doors is of a more complex nature than the loss through pores by expansion. It is a known fact that on a calm day most of this kind of loss will take place from the upper portion of the windows, being replaced by incoming currents through the lower portions and the incoming air being of greater density falls to the floor. For this reason radiators whenever possible are placed near or under windows. The incoming air being warmed from contact with the radiator circulates about and upward, gradually leaking out again. This would occasion no difficulty if the amount of incoming air remained constant, but this is not the case.

A strong wind blowing against the building will not only greatly increase the amount of air naturally coming in on that side, but will transform the natural outflow from the upper portion of the windows to a strong inward current. The warm air must escape somewhere, however, and travels to the leewardside of the building, and out through all the crevices on that side, being assisted by the pressure of incoming cold air, and attracted by the suction of the partial vacuum created by the wind on the sheltered (out) side of the building. The incoming cold air mixing with the air of the room reduces the temperature as does the escape of the mixed air on the leeward side. This necessitates the supply of a greater number of heat units to maintain the required temperature. It is always found, however, that the temperature is much lower on the windward side than on the leeward. Flue, chimney and roof losses are also greatly increased by wind pressure.



U TUBE DRAFT GAGE
BLOWER
ELLISON DIFFERENTIAL DRAFT GAGE.
3"
MOTOR
SASH HOLDER
4" DIA.
3'-11¾"
CONE
CONE
ANEMOMETER
3"
3'-4"
9½"
6'-9¼"
5"
9"
7'-11½"
ELEVATION
INCHES 1FT. 2FT 3FT 4FT
SCALE
AREA OF FAN DISCHARGE 84 SQ. IN.
3"
4" DIA.
2'-6"
12"
7"
ELLISON DIFFERENTIAL DRAFT GAGE
U TUBE DRAFT GAGE
3"
OPENING IN CONE 84 SQ. IN..
PLAN

FIG. 1

All these facts have been known to heating engineers for a long time, and provision for leakage losses arrived at by a rule of thumb method acquired by long, painful and costly experience. It has been usual to add to the radiation on the sides of the building exposed to the strongest wind effect an uncertain amount of extra radiation, and to the whole building another uncertain amount. If the guess was successful, the engineer or contractor "made good", if not, he did not. The whole amount of extra radiation thus used amounted to, according to conditions, from 50% to 100% of the amount actually necessary to heat the building with normal leakage in comparatively still air; which, including the original once an hour before spoken of, amounted to at least two changes per hour. This in common use is erroneously called one change per hour. In calculating this extra amount, and in fact, in any heating calculation, a certain proportion is assigned to wall and another to glass. These unconsciously include leakage, and as most of this is assigned to the glass factor, the rate for glass is thus very high. Little or no attempt had been made to determine the exact value of leakage under varying conditions until I took the subject up a few years ago. Finding no data of record here or abroad, I made a series of tests on window frames and sash of varying clearance by subjecting them to fan pressure through an expanding nozzle tightly secured to the window frame, a similar nozzle or cone was attached to the opposite side of the frame, and the volume of escaping air measured by an anemometer. This testing apparatus is shown in Fig. 1. Sash equipped with various wind stopping devices were also tested. A slide was placed in the pressure side of the cone, and by opening it, the pressure could be adjusted to any desired point. An accurate draft gauge registered the pressures, and was checked by a "U" tube. The results were astonishing, several hundred tests were made under identical conditions, the variations being less than 1%. Each sash was tested at least ten times. I shall only give you a few typical cases. It is recognized by

builders that a sash in order to be movable summer and winter must have at least $\frac{1}{16}$ in. clearance all around, and this is taken as a standard in speaking of "loose" sash. With $\frac{1}{10}$ in. wind pressure, which equals 15 miles per hour, the amount of air passing one lineal foot of sash crevice, $\frac{1}{16}$ in. wide averaged 184.9 cu. ft. per hour, with $\frac{1}{32}$ in. clearance 105.6 cu. ft. per hour, and with the most efficient wind stopping device 12 cu. ft. per hour. During the heating season the average wind movement is from 12 to 15 miles per hour. At $\frac{5}{10}$ in.

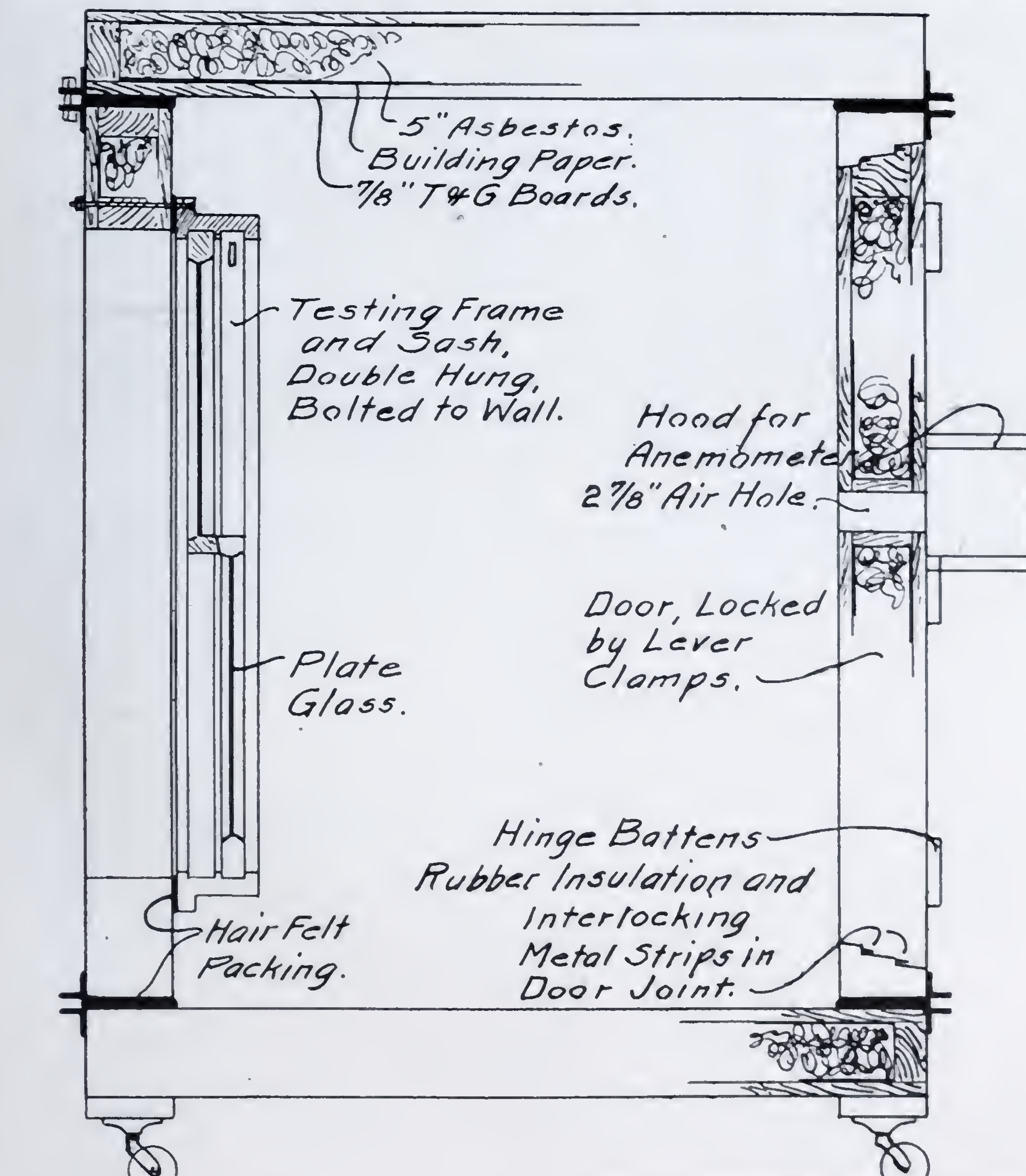


Fig. 2

pressure, or about 34 miles per hour, the figures were for $\frac{1}{16}$ in. 402, for $\frac{1}{32}$ in. 279, and for the wind stopped sash 45.6 cu. ft. per hour, respectively. This test, which was observed by several eminent engineers, showed conclusively that the leakage factor was more than 90% of a total exposure loss, the increased loss from glass and wall proper being quite small. It was at once apparent that if efficient means of con-

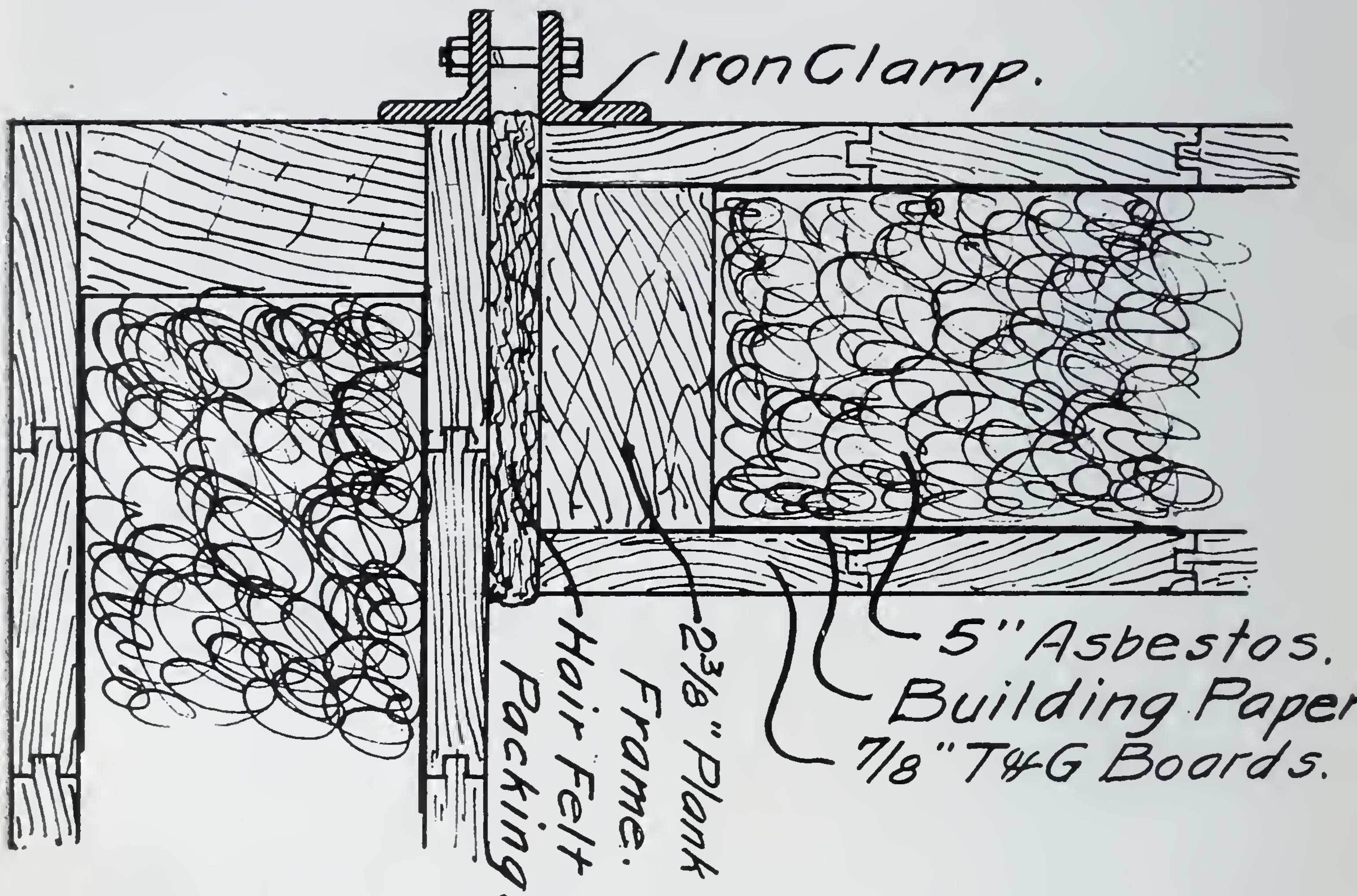


FIG. 3

trolling the effect of the wind in and out leakage through these crevices could be used in the building specifications and construction, and the engineer be aware of the fact, he could dispense with a large portion of the extra radiation heretofore necessary, as well as the "factor of safety" which he usually added to protect himself.

These results when published were stated to be comparative only, but were criticised, the contention being that the air from the fan being confined in a chamber would not have the same effect as air in the open pressing upon a building.

In order to trace the actual heat loss and check the fan results a series of tests were conducted on the roof of the West Street Building, New York City, the past winter. A testing house, shown in Figs. 2 and 3, was constructed on the principle of a refrigerator, being insulated with 5 in. thickness of mineral wool, and lined with chemically treated paper. This was placed on castors on a platform 7 ft. above the roof, so that it might be easily turned to face any prevailing wind. An opening was made in one side for a window 2 by 4 ft. in size. The window frame was then bolted on the inside against a felt gasket. The door opposite the window was made to close perfectly tight. In the center of this door was a hole containing 7 sq. inches, which had a removable plug, and was protected by a box hood, so that an anemometer placed against it would not be affected by eddying currents. Records of outside wind velocities were kept and various sash were tested as also were various wind stopping devices.

In this paper I shall only give the comparative results of a $\frac{1}{16}$ in. clearance, and the most effective wind stopping device found, which are as follows:

AIR LEAKAGE THROUGH ORDINARY AND WEATHER STRIPPED WINDOWS.

Double Hung Window 2 ft. wide x 4 ft. high.		
	Cubic feet per minute leakage through space 14 feet by $\frac{1}{16}$ inch in above window	
Velocity of outside wind per hour	Weather Strip Sash	Ordinary Sash
6 miles	1	12
9.1 "	1.6	19
9.6 "	1.75	20
9.5 "	1.65	19.6
Under 6 miles per hour no perceptible leakage could be detected through weather stripped sash		

TABLE NO. 1.

The application of this device is shown in Figs. 4 and 5, and consists of a sheet of metal, zinc or bronze may be used, covering the runway of the sash and having an extended rib with a beaded edge extending ⅜ in. into a groove in the sash. This also extends across the head and sill. That in the

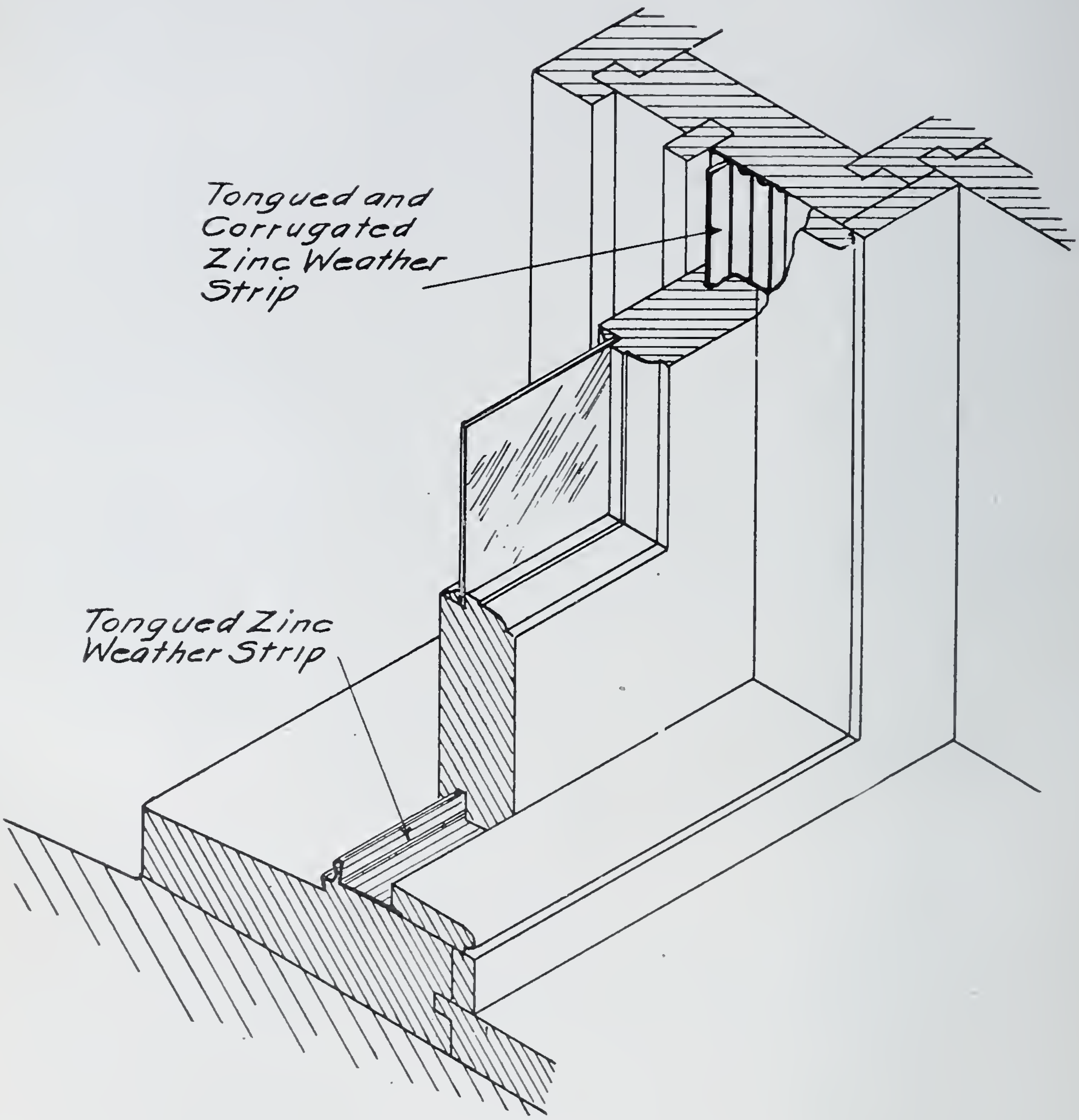


FIG. 4

runway is corrugated to reduce friction. The meeting rails are provided with interlocking male and female members as shown in Fig. 6. The comparison obtained shows practically the same leakage and ratio as obtained from the fan. The reason for this is that when the wind blew directly on the

sash, the air in the window recess was held in place by the sides of the recess, which prevented lateral movement of the air and formed a cushion on which a continual pressure was maintained by the wind in the rear.

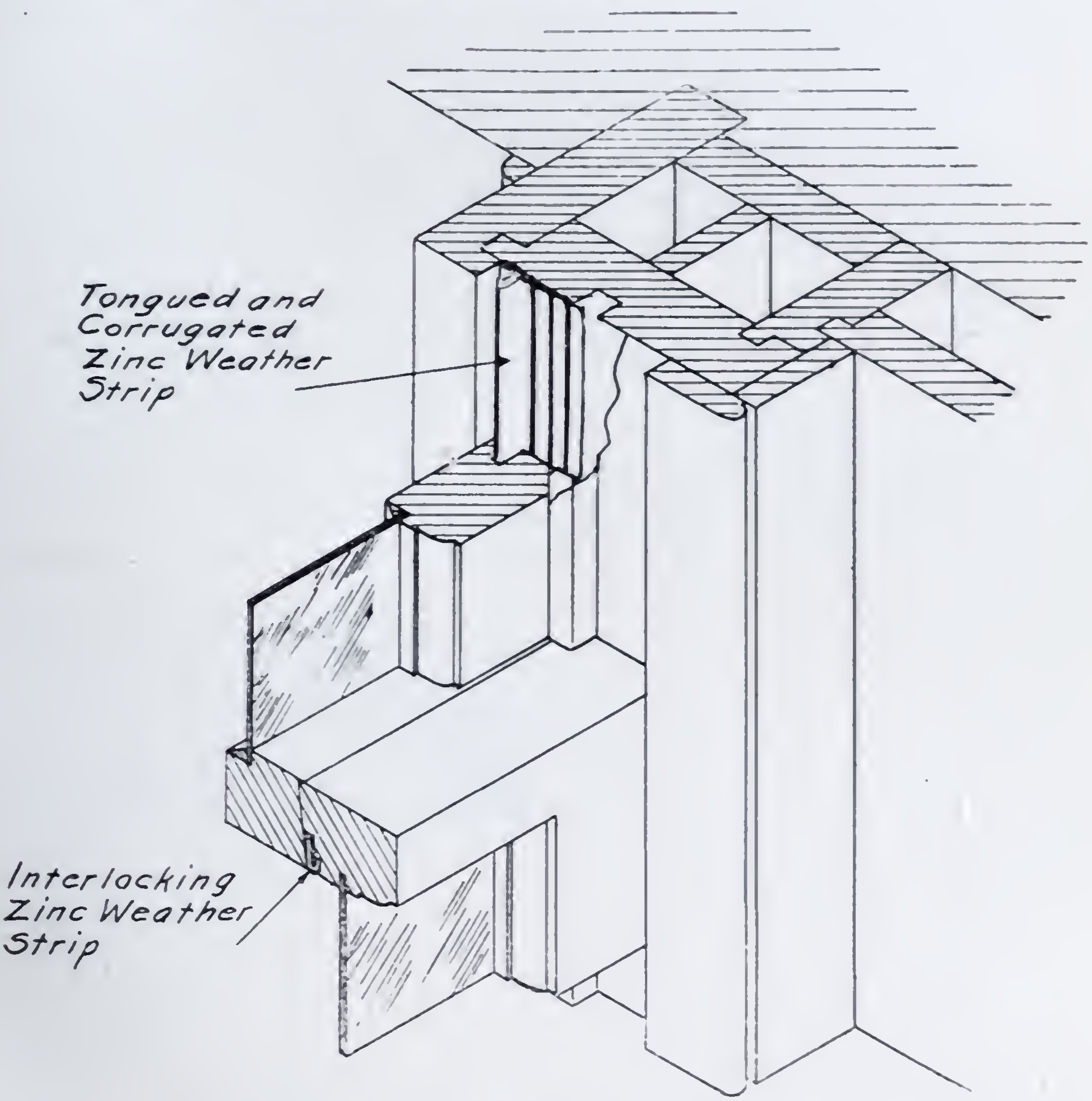


Fig. 5

The next step was to determine the heat loss caused by this leakage. In Fig. 7 a view is given of the platform, two sides of the apparatus and the window, and in Fig. 8 the other two sides, door, hood and shelf for testing instruments. An electric radiator was placed inside the testing house, the contents of the latter being about 80 cu. ft. Fig. 9 shows the interior and location of the radiator, which tested out about 796 watts with an average current of 114 volts, a watt-meter,

volt-meter and ammeter were attached and placed on the shelf shown. These were special instruments loaned by the Western Electric Company. To the left of the shelf is a common hand switch. The plug in the rear was removed, the current turned on and time noted in which the interior temperature raised a given number of degrees. The current was then shut off and time noted in which the temperature returned to the starting point. In order to get as great a difference between outside and inside temperatures as practicable, most of the tests were from 70 degrees to 80 and back to 70. A record of outside temperature and wind velocity was kept carefully. On reaching 70 degrees the switch was thrown on again, and the operation continued for several hours, thus getting a "saw-tooth" curve, which varied at first on account of absorption of heat by the walls. After a time this absorption practically ceased as did the curve variations.

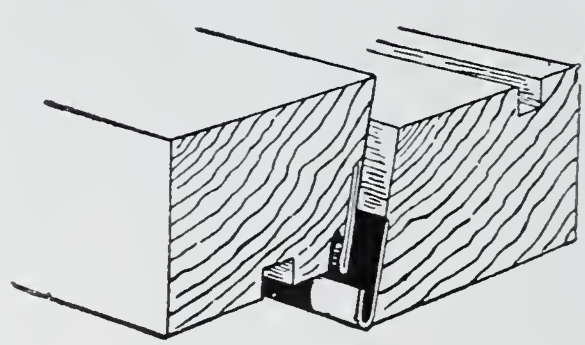


FIG. 6

This test was very tedious covering a long period of time, as it was difficult to get similar conditions on different days. Enough was learned, however, to show that the heat loss caused by leakage was much greater than had ever been supposed. In one case to quote from my discussion at the Semi-Annual Meeting of the American Society of Heating and Ventilating Engineers on July 21, 1908, at Niagara Falls, "with outside temperature at 32 degrees, wind 4 miles per hour, with loose sash, it required 38 minutes to raise the interior temperature from 72 degrees to 82 degrees, and twenty minutes for it to return to 72 degrees, with metal stripped sash, wind 4 miles per hour, outside temperature 53 degrees,

it required 20 minutes to raise from 72 to 82 degrees, and 39 minutes to return to 72 degrees."

Another table showing results of tests is as follows:

Outside Temperature, 33½ degrees to 34 degrees. Wind Velocity, 3¾ to 4 miles per hour.			
Time required to heat 80 cu. ft. 12 degrees		Time required to lose 10 degrees from 80 cu. ft.	
Ordinary Sash	Weather Strip Sash	Ordinary Sash	Weather Strip Sash
38 minutes	22 minutes	20 minutes	37 minutes
(Outside temp. 35 degrees; wind, 1½ to 2 miles per hour.)			
26 minutes	20 minutes	34 minutes	43 minutes

TABLE No. 2.

The last table shows the tremendous ratio of increase in heat loss as the wind increases. The writer is engaged in a further and more technical calculation of the tests made last winter, and will make further tests in the far North early in the coming winter. The results will be incorporated in a paper he is preparing for the annual meeting of the American Society of Heating and Ventilating Engineers in January, 1909. The main practical points are given in this paper, at least enough to enable a competent engineer to take advantage of them.

Let him calculate his heating lay-out in the usual manner, using any standard method, allowing the usual amount for leakage, exposure, etc., then take the number of lineal feet around the inside of window frame, adding the width of the meeting rail, or what is the same thing, twice the height and three times the width and deduct from his original calculation 35 to 40 Heat Units for each lineal foot of sash treated as in Figs. 4, 5 and 6. He may also dispense with 85% of the radiation added for exposure of glass surfaces. This will usually result in a heating plant 15% to 25% smaller than at first laid

out, and the reduction in annual fuel consumption will show a still greater ratio of saving. As an example of what this means, I may say, a year ago Mr. John D. Small, Engineer for the D. H. Burnham Co., on account of the fan tests before mentioned, omitted from his plans for the Oliver building in this city, 10,000 ft. of radiation, which he had originally calculated for exposure. The sash in the building being treated as in Figs. 4, 5 and 6.

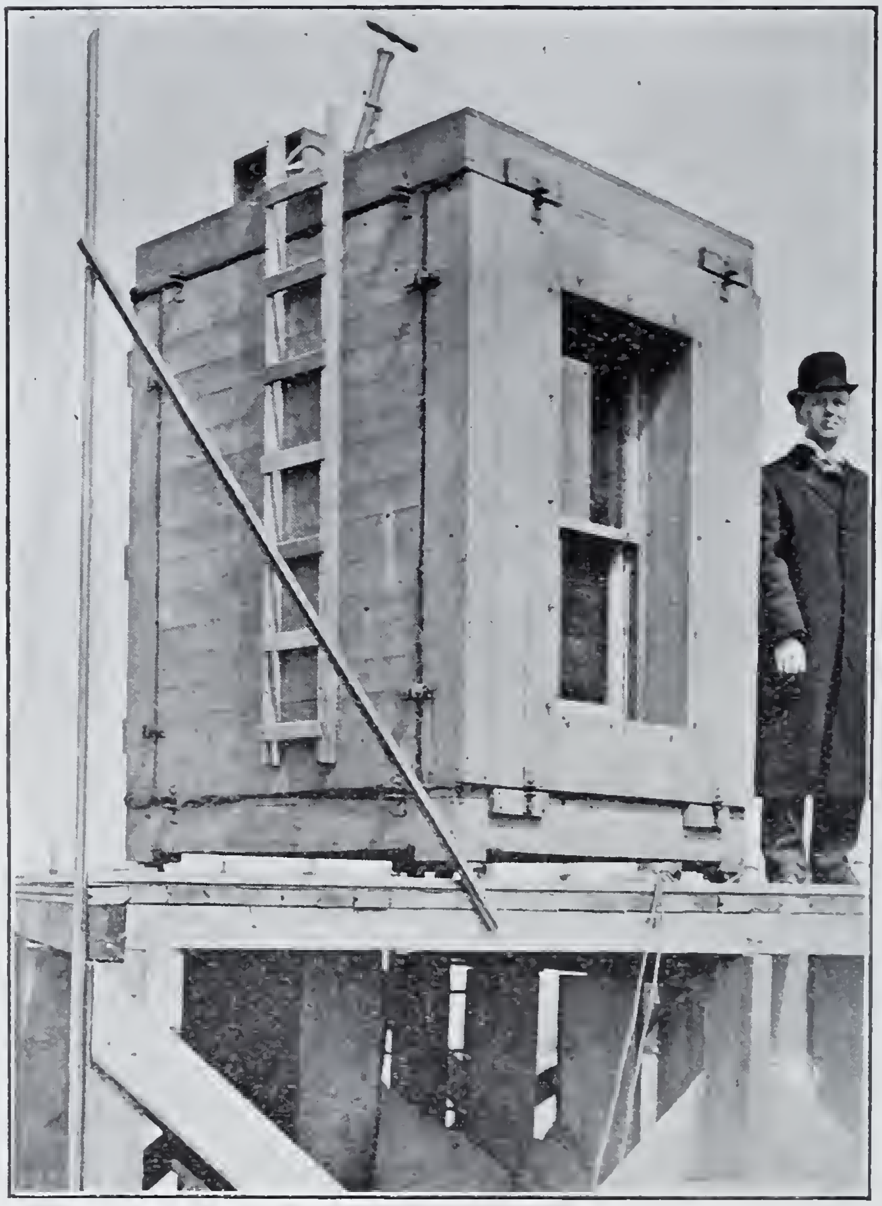


FIG. 7

It will, of course, be understood that where hot water is used as a heating medium, the saving in cost of installation will be greater than in the case of direct steam, as hot water requires about 40% more radiating surface than steam.

Since the publication of the radiator tests of last winter, (there had been a few brave ones previously), many prominent consulting engineers are insisting that they be allowed to control the window treatment, some even going so far as to provide for this in their own specifications. It will be a matter of surprise to many to know the aggregate opening around a window 3 ft. wide, 6 ft. high, with $\frac{1}{16}$ in. clearance is 21 ft. lineal opening or 252 in. by $\frac{1}{16}$ in. equals 15⅛ sq. in.

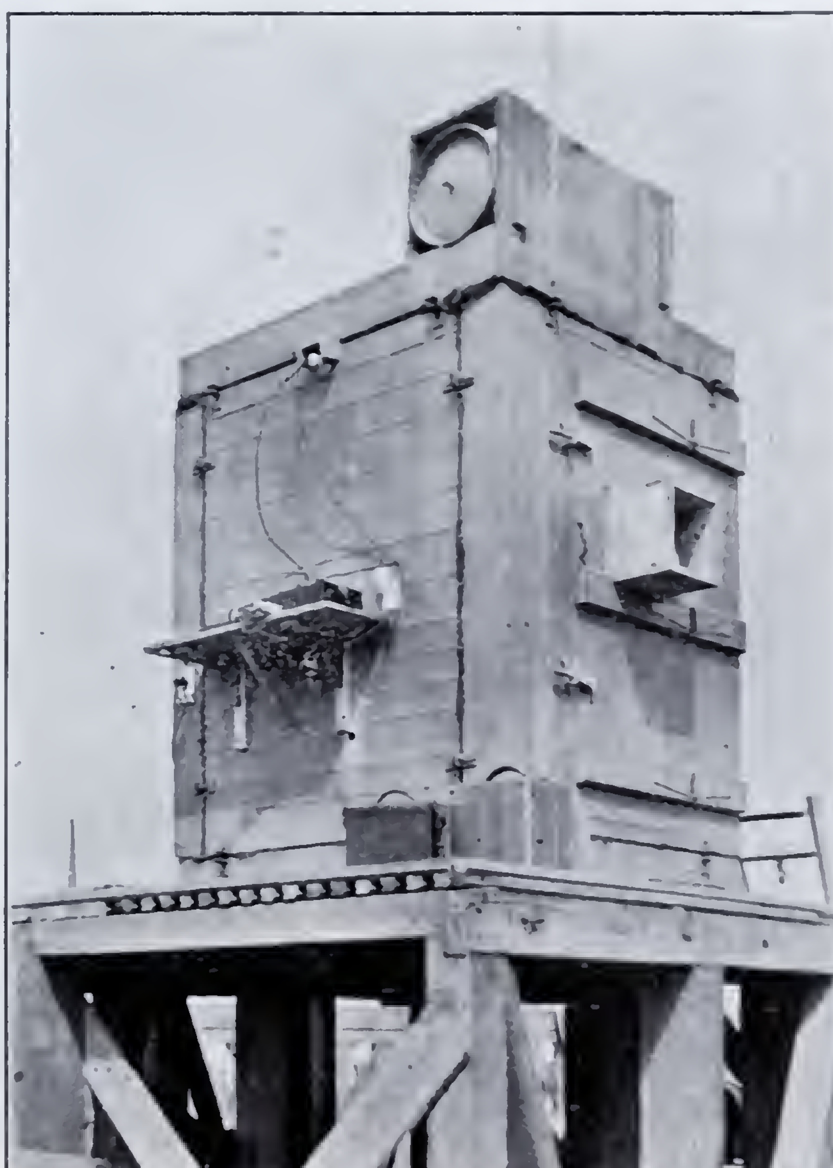


Fig. 8

While inspecting a building in this city recently where the windows were very poorly fitted and of large size, with an average clearance of over $\frac{3}{32}$ in., I found the aggregate opening for 150 windows to be between 45 and 50 sq. ft. When

one stops to consider that the size of the intake for a fan to heat this building would not be over 20 sq. ft. it is easy to imagine the effect that a strong wind would have on the heating plant of such a building. It may be urged that in a building heated by direct radiation, that is, by radiators placed in the rooms to be heated, that if all the window crevices are practically sealed, there would not be sufficient fresh air admitted for good ventilation. This would probably be true if they were actually sealed so they could not be opened and the conditions would be reduced to about the original one change per hour, hardly enough for the health of the occupants. By using the device shown in Figs. 4, 5 and 6, any desired quantity of air can be admitted by raising the sash, the device facilitating rather than retarding that operation. A window opened sufficiently to allow a pencil to be placed on the sill will cause a break at the meeting rail which will admit a considerable quantity of air. On the other hand, if the weather is cold and the wind high, the windward side of a building can be completely closed at will, if desired.

Thus far I have considered direct heating plants only, I shall now take up briefly indirect heating. If a hot air furnace is used, it is frequently impossible to heat the windward side of a house. This difficulty is remedied when the windows are properly treated, and as the air is changed frequently by this method it is not necessary to open or shut the windows. This would also apply to what is known as the gravity indirect steam system where the air is heated by passing over steam pipes in the basement before passing up the flues.

When a fan is used to force the circulation of warmed air through a building, the inlet flues, in the most accepted practice, open in the wall at a point higher than the heads of the occupants and the vent flues near the floor, both openings being placed with relation to each other, so as to obtain uniform distribution throughout the room. This distribution is often helped by deflectors placed in the inlets. It is apparent during this circulation that the warmed air in order to be effective must be of a desired temperature at the "breathing

level" of the room. All warmed air escaping by crevices above this point, or in fact by any other means than the regularly provided vents is absolutely wasted. It can readily be seen that if the upper part of a window be opened in a room heated in this manner, until the space equals the size of the inlet,

FIG. 9

that most of the incoming air from the inlet will pass out of it above the breathing level, if it were a calm day. When the wind blows air will be forced in through all the window crevices on the windward side, and mixing with the warm air reduce its temperature, above, at and below the breathing line.

The movement of air through the vent flue will be accelerated to the extent of the in leakage.

On the leeward side of the building the partial vacuum on the sheltered (out) side will act as a continual suction on the warmed air, drawing it out above, at and below the breathing line, and the movement of air through the vent flues retarded to the same extent. All such loss above the breathing line is absolute waste because it has performed no service, but simply "came right in and turned right around and went right out again." That portion at or below the breathing line has also been depleted. In order to attempt to correct this condition as it stands, the fan must be speeded up, expending more horse power. This condenses the steam in the indirect radiators faster, because more air is passed through them. This necessitates a greater activity with the coal shovel or accelerates the gas meter, and in spite of all, the condition is not wholly corrected. Ninety per cent. of this waste is needless and in these days of scarcity of gas and approaching scarcity of coal is criminal.

To illustrate just what this means I will cite a copy of a letter from the files of a local school board.

"At a regular meeting of the. . . . . . School Board, your request for a comparison of our gas bills since we had your device in our building has been granted by unanimous vote of the Board, and the saving is $80.25. From Sept. 1903 to Feb. 1904 our bill was $325.00. After having your device placed in the windows, Sept. 1904 to Feb. 1905 it was $244.75.

Very respectfully yours,

(Signed) President and Secretary.

This is a copy of a letter mailed to a local contractor, and I am informed by the secretary of the board that the windows were treated in substantially the same manner as shown in Figs. 4, 5 and 6.

There is still another important feature to this question to be considered. Air filters and washers are coming into use very largely, all the air being taken in through the fans is

strained through cheesecloth screens, washed by films of spray, and after being carefully ironed and dried to the proper degree of humidity by the indirect radiators, is distributed through the building. Numerous types of air washers are on the market or in preparation. The chief difficulty encountered so far has been the clogging of the spray nozzles, but this will undoubtedly be overcome. In some states and cities air washing and filtering is required by law in the schools, municipal and state hospitals and other types of public buildings. This is a great advance, but it is absurd to distribute this carefully laundried air through a building and immediately mix it with the dust and microbe laden air from the window crevices.

Mr. A. B. Franklin of Boston, one of the pioneers of ventilation, in discussing this question at the annual meeting of the American Society of Heating and Ventilating Engineers in January, said in part:

"I had occasion to do work on a school building in Massachusetts, and a test by the State Inspector showed that during high winds from 50% to 60% more air came out the vents than the heating system supplied. During these conditions the children had to be moved away from the windows."

I should think it quite likely. In this case, or even in one where the windows were not nearly as bad, it is evident that the work of the air washer and filter would be undone, and its cost and maintenance wasted.

Fuel economy is imperative in this country, and its waste is criminal. Burned gas and coal cannot be replaced. It is said we can by wise reforestation preserve our timber, and in a few generations renew it, but it took more than a few generations to make coal, and we do not know how to make natural gas. I believe I am well within the figure when I say that 25% of all the fuel used in the United States for heating purposes is needlessly wasted. I have recently seen plans of a public institution to be built in this part of Pennsylvania in which the architect, after visiting many similar institutions in various states, in order to find a good method of ventilation was logically compelled to make all his windows immovable parts

of the walls in order that circulation of air might be perfect. The only movable outer opening in this building is the door. He will have a perfect ventilation, and may wash and iron the air with a clear conscience.

It is for the engineers of this country to carry on this work. I may say, that the heating engineers have a double reason for doing so; one is because of its economic value, the other is that he is sure of fulfilling his guarantee to the architect or owner, and has not to wait several years for his final payment.

DISCUSSION.

Mr. E. K. Hiles: I would like to ask Mr. Whitten if he has any data on heat losses in reinforced concrete buildings as compared with ordinary brick buildings.

The Author: I have heard frequent complaints from various cities that the usual amount of heating surface for the same thickness of brick wall did not seem to answer for concrete structures. Just what the factor would be for that difference I do not know. Tests are being conducted in several places now and the matter will be gone into quite deeply the coming winter.

Mr. E. K. Hiles: Referring to the trouble experienced in air washing plants with the clogging of the spraying apparatus, do you know whether the expedient of using water under pressure has been tried? The various spraying apparatus manufacturers, notably the Goulds Manufacturing Company, of Seneca Falls, have gotten out some very successful types of spray nozzles in which removable hardened steel discs are used to reduce wear. A very fine spray is secured under a pressure of 75 to 125 lb.

The Author: I do not know whether that has been tried or not. At the meeting of the Heating and Ventilating Engineers this summer, Mr. Samuel Kauffman, of St. Louis, claimed to have solved the problem of the clogging nozzle, but as his patents were pending he did not tell how it was done.

Mr. Richard Hirsch: I know of a plant where they use

coke, keeping it well sprinkled. The air is well cleaned, but it carries an undue amount of moisture. I would like to ask if any washers have means of drying the air after it goes through the spraying apparatus?

The Author: I do not know of any satisfactory ones. Of course where air is washed and introduced to indirect radiation the moisture will be reduced to a great degree.

Mr. J. F. Esperon: I believe only one manufacturer of air washing devices, a Chicago firm, attempts to remove the moisture. They employ a system of baffle plates so arranged that the air in passing around sharp angles deposits much of the moisture. This has been used with good success in a heating plant we installed in Chicago.

Mr. H. W. Armstrong: Mr. Whitten spoke of the value of these tests to engineers enabling them to make closer determinations of the necessary size of heating plants. At the last meeting of the American Society of Heating and Ventilating Engineers, Mr. C. B. Thompson, of the testing department of the American Radiator Co., made some comments along this line. Can Mr. Whitten give a synopsis of Mr. Thompson s remarks?

The Author: Mr. Thompson had recently returned from Europe and said in part: "What is known as the German coefficient of heat losses for buildings is used and accepted as standard all over the continent of Europe. Peclet, the French physicist, did more laboratory work along these lines than anyone else, but Prof. Rietschel has taken Peclet's coefficients and tried them out on a larger scale. If sufficient data can be gotten together to establish a set of standards for the guidance of heating engineers and architects in this country, a great work will have been accomplished. In Germany all that is asked of the heating engineer is to install the heating apparatus according to Rietschel's formulae. Then, if the heating apparatus does not heat, the builder is called upon to make good."

Mr. Arnold Stucki: It being such an important matter to have the windows tight, what is wrong with the hinged windows which are used so widely in the old country? There you

have a double joint and it closes under pressure. What is the objection to such an arrangement in this country?

The Author: There is no objection whatever if the windows and frames are built as honestly as they are abroad. The material there is far better seasoned and more attention is paid to window construction, which is very well done. It is to be regretted that architects do not give this matter closer attention, and engineers should urge them to do so.

Mr. H. W. Armstrong: What is the advantage of having windows perfectly tight when a certain amount of ventilation is required for the health of the occupants of the building?

The Author: If the walls and windows are perfectly tight, an artificial scheme of ventilation will give 100 per cent performance. But any leakage through the walls or around the windows interferes not only with the delivery of the heat, but with the artificial circulation created. In this connection I might mention one case in New York, the extension of a large museum, where it was very necessary that the air be kept free from dust. In order to perfect the air washing proposition the engineers required that the windows be sealed and that the outside walls be lined with paper and painted with an impervious paint. A suction fan, connected with the entrance halls, was so arranged that there was an outward suction from the main rooms. This arrangement, in connection with properly designed doors, effectually kept out the street dust, etc., that would otherwise have been carried in from the entrances,

Mr. T. H. Johnson: I was struck with the suggestion of making the windows tight. I can understand how you could get a pretty fair fit between the sash and frame, but I do not see how you are going to control the architect and the brick layer to get the frames tight in the walls. The room in our office building which I occupied a couple of years ago had a northwest exposure. The sash were fitted with double tongued and grooved weather strips. Sitting eight feet from the window, when there was a strong northwest wind blowing, I could feel a current of air, which on investigation I found coming, not between the window and sash, but between the casing and

plastering. I do not know how you are going to control the bricklayer to meet that proposition.

The Author: There is a device now on the market designed by Capt. J. S. Sewall, late U. S. Engineers' Corps, and in which I am interested, for this purpose. It consists of a strip of metal, often of the regular Z bar shape with unequal legs, but may be of any angle to suit conditions. It is anchored in the nearest masonry joint and extends past the space between the masonry opening and window frame into a groove in the frame. It is nailed to the latter in such a manner as to provide flexibility in case of shrinkage and forms a continuous bond between the masonry and frame.

Mr. G. E. Flanagan: The drift of the paper, and to some extent the discussion, has been that heating and ventilating ought to be entirely under control. In a volume by an English writer written many years ago, the same idea was strenuously advocated, especially with reference to dwellings. This writer leveled a few shafts of wit at his countrymen for being slow to take up what were at that time considered advanced ideas, and laid special stress upon the fact that a room could not be properly ventilated if it contained an open fireplace which tends to maintain a stratum of fresh air along the floor, at the feet of the occupants, in place of at the level of the breathing line. The typical Englishman would not, however, under any circumstances, part with what he considered his cheerful, companionable, pokable fire. A French caricature at about the same time pictured an Englishman standing upon his head in the center of the room, enjoying the open fireplace and the fresh air at the same time.

Mr. T. J. Wilkerson: I would like to ask Mr. Whitten whether metal window frames and sash can be made tight enough to prevent an excess of air from entering? I am located in an office which has metal frames and sash and at times last winter sufficient cold air came in around the lower sash to freeze water on the window sill, within fifteen inches of the radiator, with the steam full on.

The Author: I do not know of any solid metal sash that

it is possible to make sufficiently tight, commercially, to make the rooms livable, as the cost would be prohibitive. The West Street Building, where these tests were conducted, has all metal sash which are well made, but there is considerable clearance about them and during the first winter the occupants on the north and west sides wore overcoats or went home. The building has a sufficient amount of radiation for ordinary conditions, the system having been designed by one of the best engineers in New York. Conditions were remedied a little by the use of strips of wood and felt at the lower sash. Similar conditions exist in the Flat Iron Building in New York, and the new B. & O. Building in Baltimore. The local ordinance in New York provides that in fire proof buildings, metal window sash be used, covered either with bronze or Kalameined steel, and a provision is made allowing a recess in the die so that some proper stripping device can be used, making a partial bond between the sash and frame. The new Metropolitan tower is being fitted in this way.

Mr. E. K. Hiles: Mr. Whitten has with him an interesting device for showing the amount of in or out leakage around windows, which we would like to have him exhibit this evening.

The Author: The first device of this sort was used by Mr. B. S. Harrison, formerly with the Sturtevant Blower Co. He used simply a paste board cone, flattened towards the larger end where the opening was about 1 in. wide and 24 in. long. The other end terminated in an opening about 2½ in. diameter, in which an anemometer was placed. The one on the table before you is of the same design but made of brass with felt packing strips at the large end. This is frequently used by engineers when examining buildings. The velocity of the outside air being taken first at a window and then the device is pressed against the corner of the window and stop inside at different points, the anemometer giving the rate of in or out leakage. This method gives very good results.

I would like to get the opinion of any heating and ventilating engineers present on the point whether the consulting

engineer should control the window openings. Mr. Henry Adams, formerly president of the Society of Heating and Ventilating Engineers, said to me two years ago: "An architect allows me to locate my intake and vent flues and provides in his plans for them. Now it would seem that the treatment of the window openings is just as important as the size and location of the air flues. So, logically, I should put that in my own specifications hereafter."

Mr. C. B. Kennedy: This matter did not come to my attention until I heard Mr. Whitten last summer, but since then I have had occasion to lay out one or two heating plants, and found that the data gathered at that time helped me a great deal, especially for windows with leaded glass. Heretofore I had simply taken a rule of thumb formula for figuring heat loss at the windows.

Mr. E. K. Hiles: I would like to ask Mr. Whitten if he has modified any of the existing formulae for calculating radiation, using the data which he has gathered.

The Author: For my own use I have evolved a formula which I will give:

$$\left(\frac{W}{4}\, d\, n\right) + (G\, d n_1) = \text{heat loss in B. T. U.,}$$

in which W = sq. ft. exposed wall

G = sq. ft. glass surface

d = difference between inside and outside temperature

n = leakage factor for wall

= 1.5 to 2

n_1 = glass factor for exposure, leakage, etc.

= 1.1 if windows are properly sealed with metal strip, otherwise use same factor as for wall.

In other words I add only 1/10 for exposure and high wind to the glass, but add the full amount to the wall, providing that the glass has been figured in the proper fashion.

Mr. H. W. Armstrong: That would be reducing the radiation in the building about 20 per cent, would it not?

The Author: That would be about it. In a government building on Ellis Island where a vacuum system is used it worked out with a reduction of 20 per cent. In the La Salle Hotel in Chicago it was 18.2 per cent. It all depends on the amount of glass in the building that has been protected.

Mr. E. K. Hiles: About what was the percentage of reduction in the Oliver Building in this City?

The Author: About 15 per cent of the radiation was omitted, but no reduction was made in the body of the calculation for that building. Mr. Small, when he first saw these blower tests, said he had not enough confidence in them to cut out all he had added for exposure. There was originally about 75 000 sq. ft. of radiation called for in the building, which was reduced to 65 000 sq. ft. and the contract will be let on that basis.

Mr. Peter O'Neil: I understand everything you have said this evening is with reference entirely to steam and not hot water. With hot water would you add 40 or 50 per cent to the radiation required for steam?

The Author: That depends. I have made good hot water plants with 40 per cent added.

Mr. E. K. Hiles: It depends altogether upon the glass.

The Author: Entirely, because the wall coefficient seems to be equitable. For years builders have been testing materials and building thick walls, paying a great deal of attention to heat holding properties. In this particular building we are in this evening, the walls are very fine indeed, but every few steps you have 20 sq. in. of hole straight out doors. It would seem absurd to put so much expense in the walls and in the same room put holes through that no man can tell what they are going to be until the contractor gets through with it.

Before the Mechanical Section, October 6, 1908.

Chairman G. E. Flanagan
Presiding.

SPRING FORMULAE SIMPLIFIED.

By Chester B. Albree,
Member.

Springs of various forms have been used from the earliest days, even in the Old Testament we find reference to archers and their bows, which are one type of springs; but surely the old warriors judged the strength of their bows, not by mathematical computation of stress and strain but by actual test; much to the discomfiture of their enemies.

Today we use springs in our warfare, but it is a warfare of intellect in its struggles to utilize to the fullest extent all that nature has given us, to maintain and support ourselves. To succeed, we must study natures laws, and adapt the various materials we find around us, to our purposes in intelligent accordance with these laws. Scientists and engineers have discovered many of nature's laws, but none have been of so much use to mankind as those relating to the strength and qualities of materials and the strains and stresses arising in their use. In fact, we may say that the present advanced state of civilization is principally due to our increased knowledge of the laws governing materials of construction.

The theory of springs is based directly on the laws of elasticity which have been well worked out, although we may still be somewhat hazy as to the "why" back of these laws. Possibly within a short time the studies now in progress as to "ions," "electric attractions" and atomic and chemical final elementary conditions, will lead to more intelligent knowledge, but meanwhile we are assured as to the laws themselves.

The fundamental laws regarding flat springs are those relating directly to the strength, flexture and elasticity of beams,

and will not be discussed in this paper. In helical and spiral springs the laws are derived from the study of bars in torsion, for it was discovered years ago that a very large proportion of the strength of helical springs came from the torsional resistance and but a minute fraction from the transverse elastic properties, so that the formulae in use generally entirely neglect the latter.

Much has been written on the subject and one of the most lucid and comprehensive treatises is by Young, published in England in 1890, Vol. 101, Transactions of the Institute of Civil Engineers. Another excellent mathematical discussion is by H. E. Wimperis, published in the "Engineer," London, November 30, 1906. Rankine, Weisbach, Reuleaux, and others equally famous, have written extensively on the subject. Each gives mathematical formulae as to the power and deflection of helical springs, but in complicated form, rendering their application to a specific problem involved and difficult.

Having had occasion to design some helical springs, the writer found very considerable divergence in the engineers' hand books and other published tables of springs, and on referring back to the quoted authorities, found the formulae, though based on correct theory, very cumbersome for every day use. A careful study of the various formulae, showed agreement in principle, but much divergence in the constants used. Further investigation showed that others had encountered the same difficulty and had given material aid towards practical results by conducting series of careful tests of springs of various sizes to determine accurately, the constants needed. These results have been published, and quite accurate spring tables and diagrams are accessible. The Westinghouse Companies and the local spring manufacturers use carefully worked out slide rules, especially designed for springs from which one can very quickly get any information desired, but unfortunately, most engineers do not have these slide rules. Among those who have contributed valuable data on the subject, may be mentioned Begtrup, Henderson, Cloud & Roy, Trevelli, Adams, Hartnell, French, and Thos. H. Johnson of Pittsburgh.

All of the formulae, being derived from the torsion formulae involving the polar moment of inertia, deal with the third and fourth powers of the diameter of the steel bar or wire of which the spring is made, thus complicating the arithmetical work of substituting fractional values of an inch for diameters of coil and wire. As an instance, Reuleaux' formulae are given here:

$$P = S \frac{\pi}{16} \frac{d^3}{R}$$

$$F = \frac{32}{\pi} \frac{P R^2 L}{G d^4}$$

in which P = supporting power.

S = strain per sq. in. in outer fibers.

d = diam. of wire.

R = radius of coil to center of wire.

L = straight length of spring wire.

F = deflection of entire spring.

$$G = \text{modulus of torsion} = \frac{2}{5} E.$$

$$= 12\ 500\ 000 \text{ as generally used.}$$

In comparing the various formulae, it was found certain quantities could be combined giving formulae of much simpler character, and yet equally exact. This was accomplished by cancellations and reductions, eliminating the 3rd and 4th powers, replacing them with areas, diameters and constants. This discussion is not original in the sense of giving any new information on the subject, but only an attempt to simplify existing formulae and to render the solution of helical spring problems easy for anyone having standard tables of areas and decimal equivalents at hand. The writer is not in the spring manufacturing business and is not an authority on the subject. The details of the simplification will be given at the end of this

discussion, but the formulae derived with the terms used, are given here:

$$P = \frac{a\ d\ S}{2\ D} \qquad f = \frac{D^2}{40\ d} \text{ for } S = 100\ 000 \text{ lb.}$$

$$\frac{P}{W} = \frac{f}{f_2} = \frac{F}{F_2} \qquad = \frac{D^2}{50\ d} \text{ for } S = 80\ 000 \text{ lb.}$$

$$n = \frac{H-1}{f + d} \qquad = \frac{D^2}{67\ d} \text{ for } S = 60\ 000 \text{ lb.}$$

$$F_2 = n \frac{D^2\ W}{40\ d\ P}$$

$$f_2 = \frac{P}{W\ f} \text{ etc. etc.}$$

in which P = closing load of spring.
S = torsional strain, outer fiber.
W = any load on spring.
f = deflection of one coil under closing load.
f_2 = deflection under any load.
F = total deflection under closing load.
F_2 = total deflection under any load.
d = diam. of bar or wire.
a = area of bar or wire.
D = diam. of coil center to center of bar or wire.
H = free height of coiled spring.
n = number of free coils.
G = modulus of torsion.
= 12 500 000 lb.

The formulae are based on a spring being designed so that when it is closed under a certain load, the strain, S, selected, will be reached. The deflection formulae gives the pitch of coils to produce strain S, when closed. With what is known ordinarily as "spring steel" it is safe to use S = 100 000 lb.,

which is the practice of the spring manufacturers of Pittsburgh. Hence with these formulae, one can safely determine what diameter of coil and diameter of steel to use, without fear of over straining the material, and further, the pitch and number of coils for any desired range of action and what deflection will occur for loads less than the closing load, or what load will be supported for any given deflection.

As it is often convenient to have a diagram from which one can quickly determine the power and deflection of a helical spring without the labor of substitution in the formulae, and as springs are generally designated by and used in connection with, their outside diameters, a diagram, Fig. 1, was made, based on S = 100 000 lb., giving the closing loads and corresponding deflections for helical springs from 1 in. to 10 in. outside diameter and from ⅛ in. to 1¼ in. steel bars.

Comparison with a very large number of tests show this diagram to be reasonably accurate and safe to use. The formulae given also govern helical springs in tension, but the extension per coil, corresponding to deflection of a compression spring must not exceed that obtained by the formulae, or the steel will be strained more than the value of S selected.

FORMULAE AND REMARKS

Reuleaux' formulae for the supporting power of a helical spring is

$$P = S \frac{\pi}{16} \frac{d^3}{R} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

in which P = supporting power.
d = diam. of wire or bar.
D = diam. of coil, center to center of bar.

$$R = \text{diam. halved} = \frac{D}{2}$$

S = torsional strain per sq. in. in outer fibers.
a = area of the bar.

$$= \frac{\pi \; d^2}{4}$$

$$\text{then } d^2 = \frac{4\,a}{\pi} \ldots\ldots\ldots \ldots\ldots\ldots (2)$$

substituting (2) in (1)

$$P = S \frac{\pi}{16} \frac{\dfrac{4\,a}{\pi} d}{\dfrac{D}{2}} = S \frac{\pi}{16} \frac{\dfrac{8\,a\,d}{\pi}}{D}$$

reducing

$$P = \frac{ad\,S}{2\,D} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Reuleaux' formulae for the total deflection of a helical spring is

$$F = 32 \frac{\pi\; P\; R^2 L}{G\; d^4} \ldots\ldots \ldots\ldots (4)$$

in which L = straight length of bar.
G = modulus of torsion.
= 12 500 000.
let h = closed height of spring.

then $\dfrac{h}{d}$ = number of coils.

πD = length of one coil, neglecting slight difference due to spiral.

and $\pi D \dfrac{h}{d}$ = total length of bar.

but $\dfrac{h}{d} = 1$ for a spring of one coil, neglecting the pitch of the coil.

then $L = \pi D$ ....(5)

let f = deflection for spring of one coil and substituting in (4) the values of P from (1) in terms of D, remembering that

$R^2 = \frac{D^2}{4}$ and L from (5) we have

$$f = \frac{32\,\pi\,\frac{\pi d^3 S}{8 D}\,\frac{D^2}{4}\,\pi D}{G d^4}$$

reducing

$$f = \frac{\pi^3}{G}\, S\, \frac{D^2}{d}$$

The numerical value of $\frac{\pi^3}{G}$ is .000 002 48

hence

$$f = .000\ 002\ 48\ \frac{SD^2}{G} \text{ ....(6)}$$

From the experiments of Roy, French, Benjamin, the Penna. R. R. and others, it is found that for good spring steel 100 000 is a safe value for S. Using this value, (6) becomes

$f = .248\ \frac{D^2}{d} = \frac{D^2}{40.32\ d}$ or in round numbers,

$f = \frac{D^2}{40\ d}$ as a working formula

Similarly for S = 80 000

$f = .1984\ \frac{D^2}{d} = \frac{D^2}{50.4\ d}$ or as a working formula,

$f = \dfrac{D^2}{50\ d}$ etc. For other values of S, as for 60 000

$f = \dfrac{D^2}{67\ d}$ etc.

From these formulae, the value of S for any given spring can be determined. If it exceeds 100 000 there is danger of over loading the spring. Similarly we can determine if f is too great or too small.

Since, within reasonable limits the deflection and supporting power of a spring, vary directly as the load, we have,

$$\frac{P}{W} = \frac{f}{f_2} = \frac{F}{F_2}$$

in which

P = closing load,
W = any load,
f = deflection for one coil under load P,
f_2 = deflection for one coil under load W,
F = deflection of n coils under load P,
F_2 = deflection of n coils under load W.

If we allow one full coil for squaring the ends of a spring, then

$n = \dfrac{H - 1}{f + d}$ where H is the free height of the unloaded spring.

The total deflection $F = n\ f$ and $H = n\ (f+d) + 1$

If X = the number of 10 000's in S, then $f = \dfrac{XD^2}{400\ d}$ for any value of S.

In springs of the same size bars, the closing load or supporting power varies inversely as the diameter of the coils, center to center of bars.

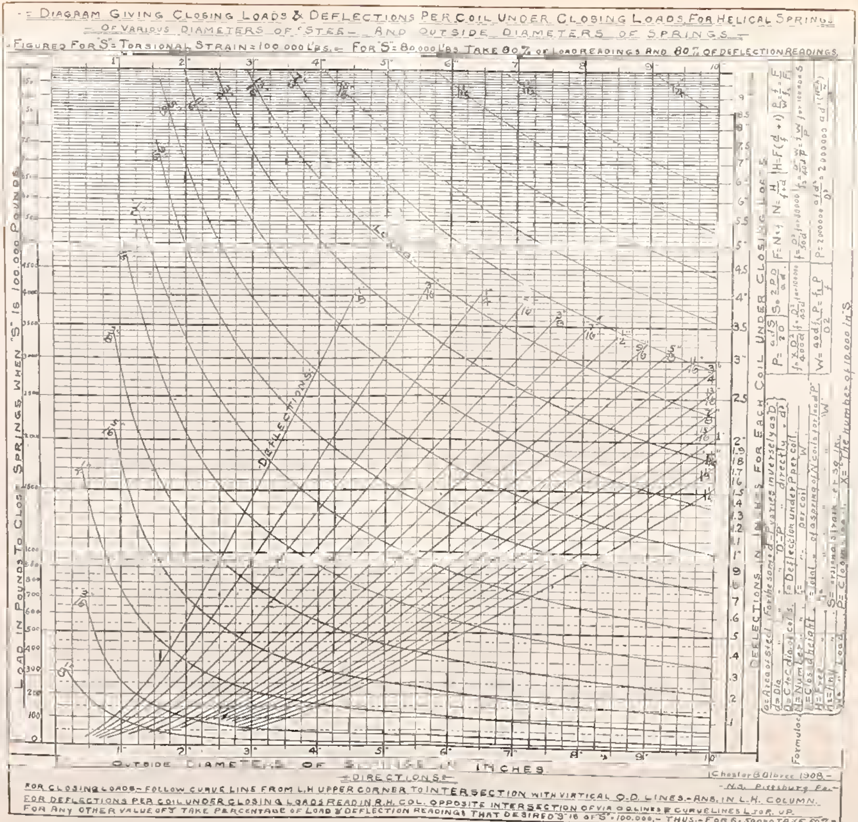


DIAGRAM GIVING CLOSING LOADS & DEFLECTIONS PER COIL UNDER CLOSING LOADS FOR HELICAL SPRINGS
OF VARIOUS DIAMETERS OF STEEL AND OUTSIDE DIAMETERS OF SPRINGS.
FIGURED FOR "S" = TORSIONAL STRAIN = 100 000 LBS. — FOR "S" = 80,000 LBS TAKE 80% OF LOAD READINGS AND 80% OF DEFLECTION READINGS.
LOAD IN POUNDS TO CLOSE SPRINGS WHEN "S" IS 100,000 POUNDS
DEFLECTIONS IN INCHES FOR EACH COIL UNDER CLOSING LOADS
DEFLECTIONS
OUTSIDE DIAMETERS OF SPRINGS IN INCHES
DIRECTIONS
FOR CLOSING LOADS — FOLLOW CURVE LINE FROM L.H. UPPER CORNER TO INTERSECTION WITH VERTICAL O.D. LINES. — ANS. IN L.H. COLUMN.
FOR DEFLECTIONS PER COIL UNDER CLOSING LOADS READ IN R.H. COL. OPPOSITE INTERSECTION OF VIA O.D. LINES & CURVE LINES L. TO R. UP.
FOR ANY OTHER VALUE OF S TAKE PERCENTAGE OF LOAD & DEFLECTION READINGS THAT DESIRED S IS OF S = 100,000. — THUS. — FOR S = 50000 TAKE 50%
Chester B Albree 1908.
N.S. Pittsburg, Pa.

Fig. 1

In the springs of the same diameter, center to center of bars, the supporting power varies directly as the cube of the diameters of bars.

Experience shows that the best proportioned springs are those in which the outside diameter of the coil is from six to eight times the diameter of the steel used.

In using the spring diagram shown in Fig. 1, when comparing springs with the formulae given, it must be remembered that in the formulae, the center to center of bars is used for diameters, and *not* the outside diameters as shown by the diagram.

It is obvious from what has preceded, that in designing a spring for S = 100 000 the pitch or distance apart of coils when free, must equal the deflection f per coil of the diagram. If this pitch is greater than the f of diagram or derived from formulae, the spring will be overstrained and if less, the spring will close with a smaller load, and the results will not be in accord with diagram or formulae. But by finding what proportion the actual pitch bears to the pitch of the diagram or formulae, the actual closing loads for any pitch spring may be obtained. This has been done by the writer with the list of test springs given in French's paper in the Transactions of the American Society of Mechanical Engineers and over 95% of the springs agree with the formulae given.

The following data from Alfred Young's paper may be of interest as relating directly to the subject.

The relative torsional values of different sections of the same area as a given circle, considering the latter as 1, are:

Ellipse D = 2d	80%
Square	88%
Rectangle b = 10 h	21%
Triangle (equilateral)	73%

Tests of hardened steel in torsion give 163 500 lb., breaking strain per sq. in. and the torsional breaking strain for same

material, was 150 080. The modulus of torsional elasticity was 12 544 000.

$$G = \text{modulus of torsion.}$$

$$= \frac{\text{twisting moment x length.}}{\text{polar mom. of inertia x angle of torsion.}}$$

$$\theta = \text{angle of torsion.}$$

$$= \frac{360 \text{ n W R}^2 \text{ C}}{\text{G J}}$$

in which

$$C = \text{a constant.}$$
$$= 1 \text{ for the circle.}$$
$$W = \text{axial load.}$$
$$J = \text{polar moment of inertia.}$$
$$= \frac{\pi \text{ d}^4}{32}$$

Mr. A. Stucki, of our Society, in Vol. 20, p. 246, of the Proceedings of the Society, states for double springs, the relation must be $D:D_2 = R:R_2$ and $L = L_2$ for correct action. Mr. Thos. H. Johnson, also of our Society, in his paper on "Static and Dynamic Forces," Vol. 10, p. 104, of the Proceedings, says, "The resistance of a spring must be proportional to the elongation of a single coil, and a spring develops the same resistance, whatever the number of coils," confirming the assumption that the deflection and power of one coil determine the action of the entire spring.

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DISCUSSION.

Mr. T. H. Johnson: Mr. Albree's paper is so simple and direct that I do not see very much to discuss. He started out to reduce a complicated formula to a simple one, and he did it. There is one thing I would like to say. He used my name in a way that would seem to imply that I was in some way or other before the public as an authority on springs. This is a mistake. The paper to which he referred only used the spring as an illustration of a parallel case to enforce a point which I was trying to make on a different subject.

Mr. E. S. McClelland: I was requested by Mr. Albree to bring here a pair of slide rules that have been used by The Westinghouse Machine Co. for about twenty years. The formula used in making up these slide rules is the same as that which Mr. Albree has simplified. We found great difficulty, as every one does, in using the original formula. Mr. Fred. H. Park, a young man connected with the Engineering Dept., took the formula and constructed a slide rule based upon it. I have here two of these rules. They are made of cherry or walnut wood, on which have been mounted strips of drawing paper upon which the various scales have been laid out on the logarithmic principle.

These slide rules, of which there are two, are based on a formula found in Kent's handbook, pages 348 and 351. One is used for selecting the spring, i. e. when the mean diameter, the diameter of the wire and the scale are known, to find the number of coils; or knowing the number of coils, diameter of wire and mean diameter of spring, the scale may be found; or any combination of these four factors may be easily determined by the use of this rule.

It consists of four scales, two of them stationary and two of them sliding, the scale representing the mean diameter of coils being graduated for springs from 1/4 in. to 14 in. diameter; the slide representing the diameter of wire divided to take care of wire diameters from .05 in. to 1 in.; the slide indicating the number of coils divided to represent from 1 to 1000; the other scale indicating the scale of the spring from 1 to 10 000 lbs., it being understood that the scale of the spring is the force to extend the spring 1 in.

The other slide rule also has two scales and two slides, and by the use of this rule, knowing the mean diameter of the spring, the diameter of the wire and the load in pounds imposed upon the spring, the fiber stress may be easily found. The scale representing the mean diameter of coil takes care of springs from 1/4 in. to 20 in. diameter. The slide representing the diameter of wire takes care of wire diameters from 3/32 in. to 1-3/4 in. The scale representing the fiber stress takes care of springs up to 100 000 lbs. fiber stress per sq. in. The scale representing the load in pounds takes care of loads from 1 lb. to 10 000 lbs.

To show how simple the operation is for figuring out a spring, an arrow on slide No. 1 is placed opposite mean diameter scale. The arrow on slide No. 2 is placed opposite diameter of wire, and opposite the scale in pounds on the upper scale of the rule we read on slide No. 2 the number of coils, making a very simple process for obtaining results from this spring formula.

I notice Mr. Albree mentioned tonight compression springs only. These scales are figured for extension springs

and there is quite a difference between the two types of springs. In earlier days we had very little difficulty in getting springs made for certain governors designed and built by The Westinghouse Machine Co., but of recent years have had a great deal of trouble through our inability to obtain springs that were satisfactory. We are dependent upon the material altogether.

Mr. Albree speaks of 100 000 lbs. fiber stress. This is high, and if we were to put it up to the average spring manufacturer he would refuse to make us springs with such fiber stress, except they be of wire under ¼ in. diameter. In all our compression springs we try to keep the fiber stress as low as 42 000 lbs. Springs that move every time an engine makes a revolution must be figured for low fiber stress because of the constant weakening of the springs in service, but with extension springs depending on the diameter of the wire, the fiber stress comes up. Some makers agree to 120 000 lbs. fiber stress for ⅛ in. and smaller wires; 90 000 lbs. fiber stress from $\frac{5}{32}$ in. to ¼ in. diameter wires, and for larger wires a gradual decreasing allowable fiber stress. For the average extension springs it is best not to exceed 40 000 lbs. as a rule.

Mr. A. J. Schaaf: The springs that we have to deal with vary anywhere from $\frac{1}{16}$ in. to 1½ in. diameter of material. We find difficulty in getting the smaller springs to stand up under the load, as we do some of the larger ones. We find spring makers who put an initial tension in the spring by twisting the wire as they wind it, so that it will not start off at zero but with 10 or 15 lbs. load. This is out of the question for governors, but it would not make any difference in a car spring.

In this connection I would like to call your attention to a patent on a slide rule for helical springs gotten out by several gentlemen in Bethlehem, Pa. The patent is No. 73840 and is dated March 8, 1904. It is a most ingenious rule and gives a very simple method for designing springs.

Mr. E. S. McClelland: Mr. Fred. H. Park spent about

$125.00 making researches trying to get a patent on this rule some eighteen or twenty years ago, and we found so many patents on slide rules,, mostly in the textile business up in New England, that there was no hope for us.

Mr. T. H. Johnson: I would like to ask how these rules were graduated. Some years ago I wanted to get a slide rule made for a special purpose and was told there was not a dividing machine in the United States that could graduate a logarithmic scale.

Mr. E. S. McClelland: This was graduated by hand, not by machine, but it has been tested out and there are hundreds of them in use. There is no patent on them; you can reproduce them yourself, and they are accurate enough for all practical purposes.

Mr. S. B. Ely: I understand under a constantly changing load the fiber stress ought to be kept within the elastic limit. Some one speaks of using 40 000 lbs., in compression and in tension 125 000 lbs. That surely cannot be within the elastic limit. Why do these two fiber stresses vary so?

Mr. E. W. Pittman: Fiber stress is simply the skin shearing stress in the material of which the spring is made. It is purely a torsional stress, and is exactly identical with the stress in a shaft that transmits torsion.

Recent experiments by Mr. Wilson Hartnell show that for steel wire the following stresses are the maxima consistent with safety:

¼ in. wire, 70 000 lbs. per sq. in.
⅜ in. wire, 60 000 lbs. per sq. in.
½ in. wire, 50 000 lbs. per sq. in.

Mr. E. V. Wurts: I would like to ask if the service into which a spring is put is not a very large factor in determining the stress. Would not a spring used on an inlet valve on an engine, for instance, require a much lower fiber stress than a spring supporting a load which is riding free on the spring? Is not the difference in fiber stress caused by the different service to which the spring is put?

Mr. E. S. McClelland: That is true almost strictly. The diameter of the material from which the spring is made also cuts quite a large figure. Take the smaller diameter wires, $\frac{1}{32}$ to $\frac{1}{4}$, they are all drawn tempered wires, and those springs we can run with a higher fiber stress than the hot rolled or even cold rolled wires. When we use the large diameters of wire we have to keep them down to 35 000 lbs. fiber stress. Most of the springs I speak of are used for valve gear, exhaust valves on gas engines or steam engines, where they must go the full limit, or governor springs in an engine, which has a difference from initial to full tension almost every moment of its operation. Of course, you have to figure according to load and service which you expect of the material. Some of the small spring makers will give you springs of 120 000 fiber stress for ⅛ in. and smaller.

Mr. F. J. Hale: Springs working continuously, such as gas engine inlet or exhaust valve springs, except those of small wire, should not have over 45 000 lbs. to the sq. in. fiber stress. Experience shows that when worked above this fiber stress the life of the spring is limited to a few years. Governor springs may be worked to 60 000 lbs. to the sq. in.

In connection with the two spring scales shown here tonight, one can hardly be used without the other. If we know the scale and want to find the number of coils, that is only part of the story, since the next question is,—what is the fiber stress? By the ordinary method quite a length of time is required to figure scale, number of coils, etc. for even a single spring, but with these scales one can run over a dozen different kinds of springs in a few minutes.

DISCUSSION OF PAPERS.

Members of the Society and also other readers of the Proceedings are urged to send to the Secretary written discussion of papers after publication, which will be printed in succeeding issues of the Proceedings. We believe that much valuable information may be presented in this way and it is hoped that this feature of written discussion may be made a prominent one in the Proceedings.

PROCEEDINGS OF THE

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VOL. XXIV. DECEMBER, 1908 No. 9

REGULAR MEETING,

November 17, 1908.

President James K. Lyons

In the Chair.

THE MERCURY RECTIFIER.

By R. P. Jackson,

Non-Member.

Ever since the introduction of alternating current machinery there has been a demand for devices of various kinds for receiving power from an alternating current circuit and delivering it in the form of direct current, for use in connection with apparatus that requires current of an undirectional nature. There are in use devices of the following types, differing widely in limiting capacity and characteristics, but all accomplishing with various degree of effectiveness the purpose desired:

Motor generator
Rotary converter
Commutator type rectifier
Switch and spark gap type rectifier
Electrolytic valve rectifier
Mercury vapor rectifier

The motor generator is entirely general in its application, as the power is delivered to an A. C. motor and by it transmitted through the shaft or belt to a D. C. generator. Any

voltage, frequency and capacity for which motors and generators may be built and wound can be handled by a motor generator set.

The rotary converter is essentially a motor and a generator combined in one machine, using the same field and armature material. Its principal limitation is that there is a nearly fixed ratio between the alternating and direct current voltage.

A commutator type rectifier is a commutator run at a speed synchronous with the A. C. supply and accomplishes a literal rectification by switching over alternate half waves so they traverse the load circuit in the same direction.

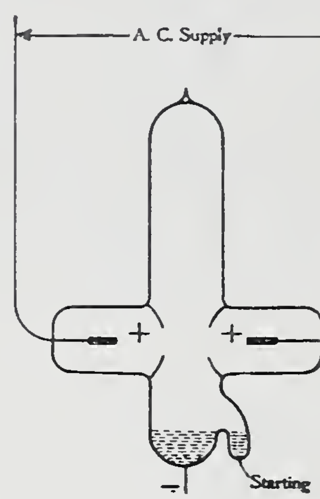

FIG. 1

Several synchronous switching devices involving the closing of relays, or the breaking down of spark gaps in such a way as to connect the load circuit to alternate parts of the A. C. circuit so that rectification occurs, have been tried with somewhat doubtful success.

Electrolytic rectifiers have been designed which make use of a certain valve action manifested by aluminum in certain electrolytes. Aluminum in many different solutions will, under the action of a current, build up a film on its surface which permits current to flow in but one direction. Two aluminum plates may be so connected, through a load and an A. C. circuit and a plate of some other metal such as lead or iron, as to deliver all the alternations or half waves to the load in the same direction. Due to the drop in voltage, caused by the resistance of the electrolyte and the more or less inevi-

table leakage of current in the wrong direction, the electrolytic rectifier cannot as a rule attain an efficiency at all high.

The mercury rectifier operates in a manner similar to the electolytic rectifier, that is, by the action of electric valves. Nearly all metals have a tendency to suppress an A. C. arc at the zero point of the current wave. Some of the metals, namely, zinc, cadmium and mercury manifest this characteristic in a very powerful degree. It is for this reason that a certain combination of zinc, cadmium and copper is used as

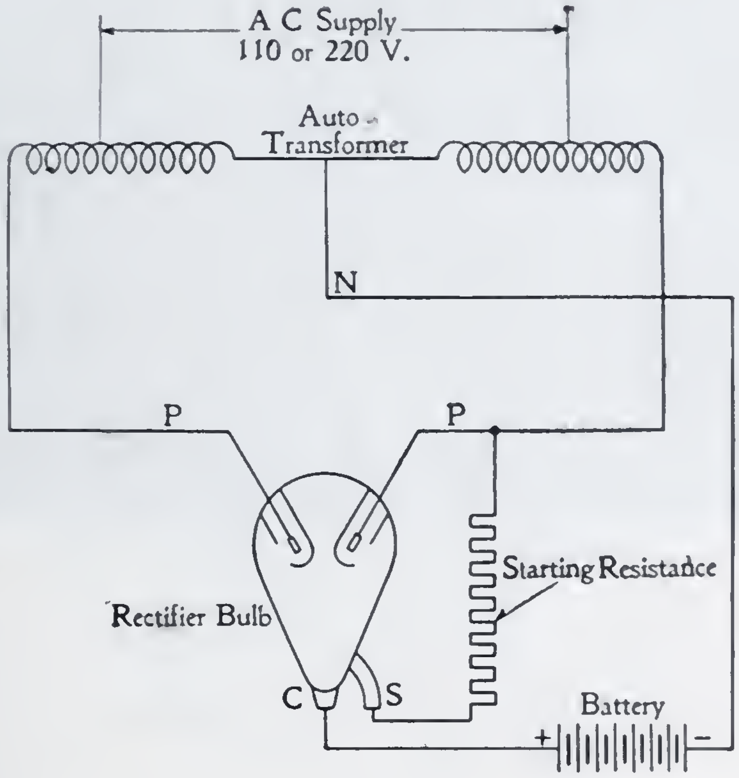

FIG. 2

a non-arcing metal in lightning arresters. Apparently this non-arcing or arc suppressing power is due to the sudden appearance of a resistance at the surface of the negative electrode as soon as the current ceases to flow even for an extremely short period. This negative electrode surface resistance is enormously increased at a condition of high vacuum, but ceases to exist as soon as a current has once started with a given electrode as continuously negative. A typical mercury rectifier bulb, or tube, is shown in Fig. 1. The two electrodes marked + are of iron, graphite or some substance that does not amalgamate with mercury. At the bottom of the bulb are

two pools of mercury, one of which forms the negative electrode. The bulb itself is commonly of glass. At the start the negative electrode resistance exists throughout the bulb, that is, at all the electrodes, and would require anywhere from 6 000 to 25 000 volts to break it down so that current could flow.

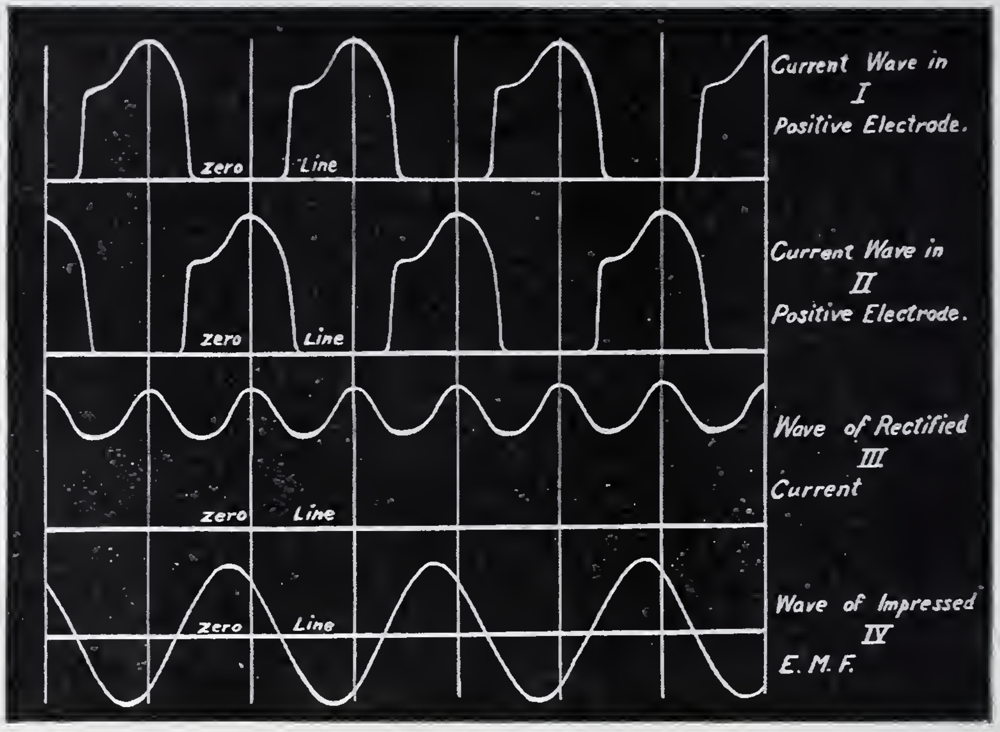

FIG. 3

The common and most reliable method of starting is to connect some source of e. m. f. across the terminals of the two pools of mercury. When the bulb is tilted so the mercury pools flow together and part again, a spark is produced. One end of this spark or small arc must be negative and the negative electrode resistance has momentarily disappeared. Before it can re-establish itself the regular operation of the bulb as a rectifier begins. This regular operation consists of alternate half waves of current passing first from one positive and then from the other, to the negative or mercury electrode, and thence out through the load and back to the middle or neutral point on the auto-transformer. Fig. 2 illustrates the ordinary operating connections when charging a battery. The starting resistance is only connected in until the bulb has started.

The writer cannot explain in detail the nature of this

valve characteristic, caused by the peculiar film like resistance at the surface of conductors, but it is considered that our conventional assumption that the actual flow of current is from the positive to the negative electrodes may be incorrect. Apparently the little particles called "electrons", described by J. J. Tompson as having a mass of about1/1000 part of a hydrogen atom, carry charges of negative electricity. A current

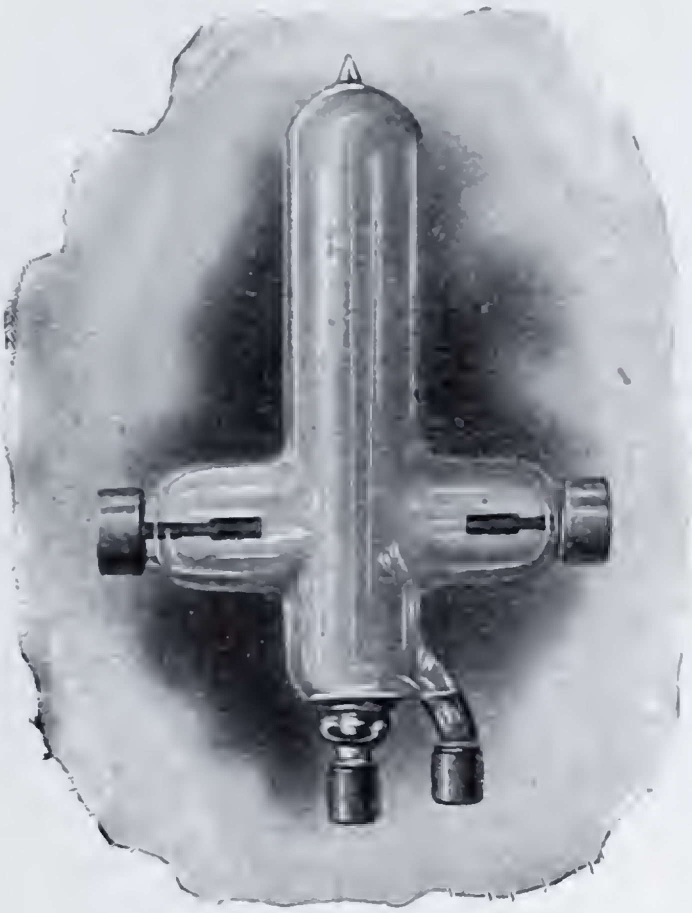

FIG. 4

consists of a certain number of these electrons moving as a stream in a conducting circuit. Whether these electrons are themselves charges of negative electricity or are simply the carriers of such charges is immaterial here. The essential fact is that they can pass from a vapor to a solid conductor, but cannot pass without initial assistance from such a conductor to a vapor unless the pressure tending to cause them to do so is enormously increased. When once a start is made through the surface, however, the rest of the vapor path between the solid conductors is easily traversed. Consequently, to get a correct conception of the action we must revise our

thought of current direction and consider the actual current flow as upward from the negative or mercury electrode to the positive. Just why the electrons, or negative charges, cannot penetrate the surface of an electrode without assistance, has been ascribed to surface tension, causing practically a skin,

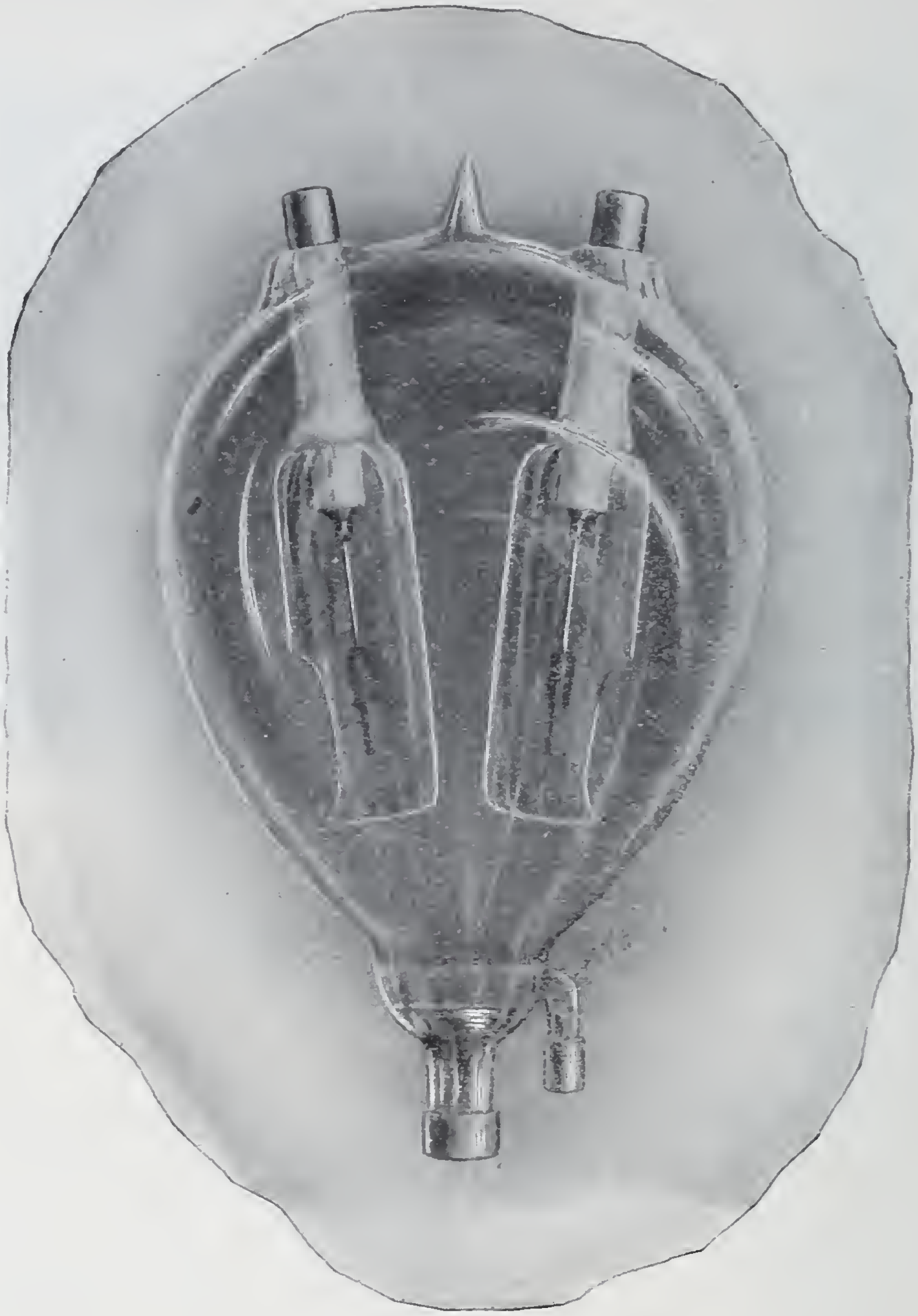

FIG. 5

or film, which has to be punctured. The fact that if the current is very small it is exceedingly difficult to maintain, indicates that the electrode skin resistance seems to reassert itself. Also, when the applied potential is high it is sometimes possible to start a current simply by shaking the bulb and breaking up the surface of the mercury into small ripples.

The total e. m. f. drop in a rectifier bulb ranges from about twelve volts up to forty or fifty. This drop is made up of about five volts or a little more, at the positive and about four volts at the negative, combined with a drop in the vapor path, dependent largely on the length and diameter of that path and also on the number of bends or angles which the path

Fig 6

takes. An increase of vapor pressure increases the drop, but an increase of temperature operates in the other direction, to decrease the drop. All other gases than mercury vapor give a much higher drop than mercury vapor and their presence even in small quantities has this effect.

The current capacity of a bulb is dependent on the section and size of the leading conductors, especially of the platinum seals which carry the current through the glass. It is

also dependent on the total cooling surface of the bulb, as there are limiting temperatures for good operation, and the only way to keep the temperature down is to give large radiating surface to the glass or to operate in oil. During operation mercury vapor, and also many small drops of mercury, are given off by the bright negative spot in the mercury which gather on the inner surface of the glass and condense into larger drops which run back into the pool again. In so condensing the heat carried passes out through the walls of the bulb and escapes.

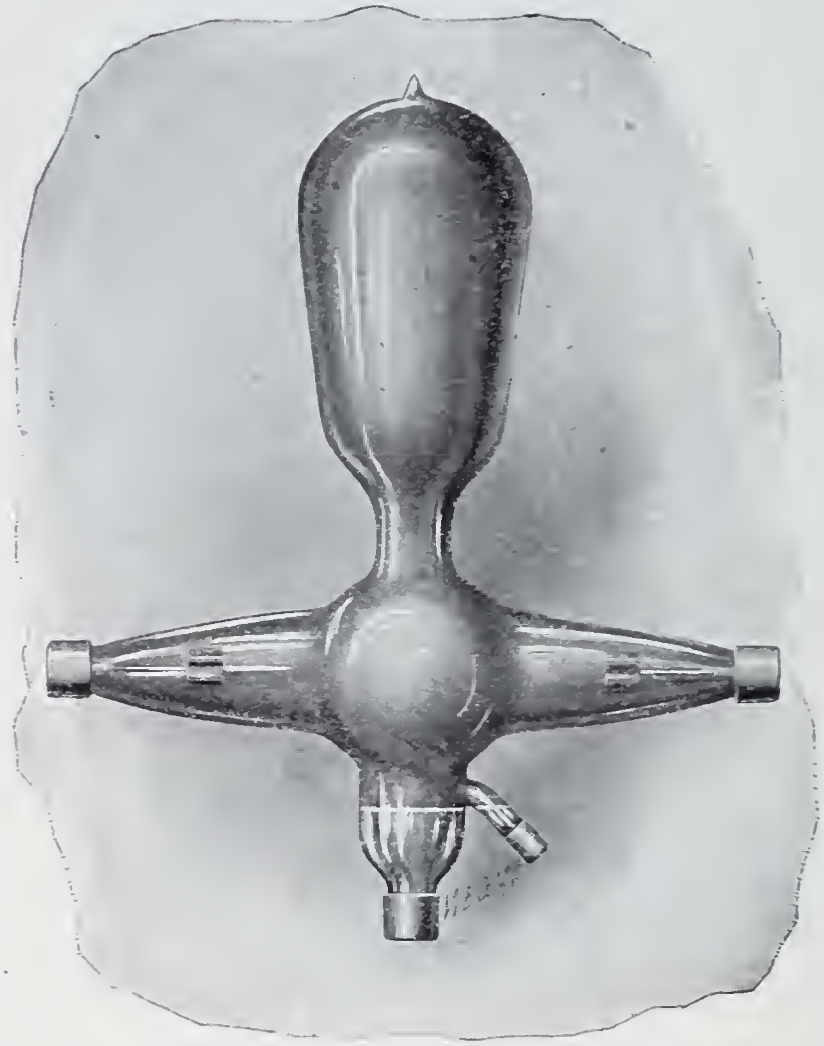

FIG. 7

The voltage which the bulb will sustain and deliver to the D. C. circuit is dependent largely on the length, narrowness and crookedness of the vapor path. A bulb has to be worked out so as not to permit even the smallest particle of mercury to spatter against or fall upon the positive electrodes, as if this happens, the negative electrode resistance is broken down at the point where such a drop impinges and the

result is a short circuit between the positives. From Fig. 2, it may be seen that such an occurrence not only short circuits the transformer but may permit a battery to feed back through the bulb and operate it the same as D. C. mercury vapor lamp with destructive effect on the bulb.

In Fig. 3 is shown the relationship of the primary e. m. f., the current from the two positives and the total rectified current through the D. C. load. Fig. 4 shows a five to ten ampere bulb suitable for delivering 100 volts or less on direct current, and Fig. 5 shows a bulb for 30 amperes which is suitable for 300 volts or less. Fig. 6 covers a so-called high ten-

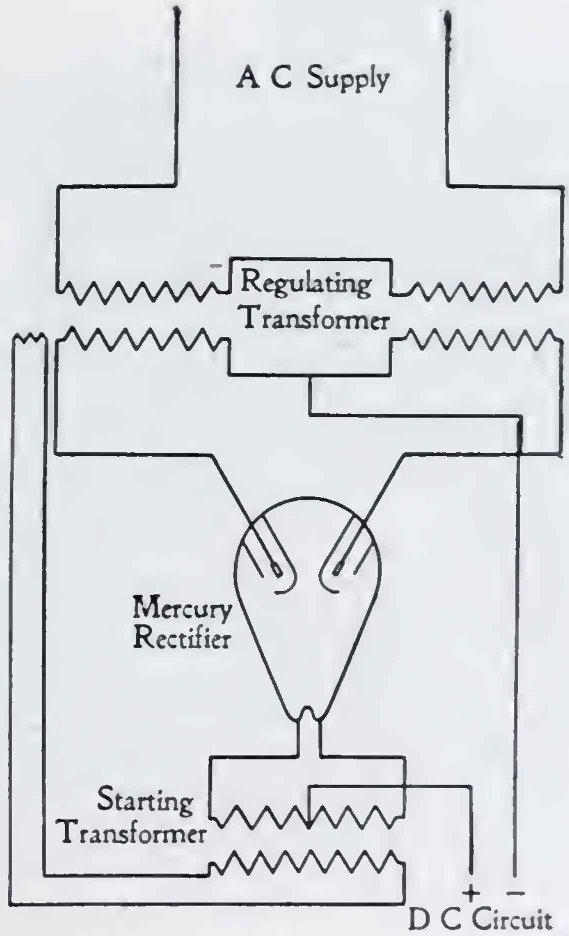

FIG. 8

sion bulb suitable for from four to seven amperes up to 3 500 volts, and is used for delivering current to series arc light circuits. Fig. 7 shows a thirty to fifty ampere bulb for 120 volts or less.

It will be noted from Fig. 3 that the direct current is not uniform, but is pulsating. If there were no reactance in the D. C. circuit, or its equivalent, the current would drop to zero

at each point where it dips down and in reality the bulb would go out. By including a certain amount of reactance in the D. C. circuit or its equivalent, properly placed in the auto transformer, enough magnetic energy is stored during one half wave to maintain the circuit from one position in the bulb

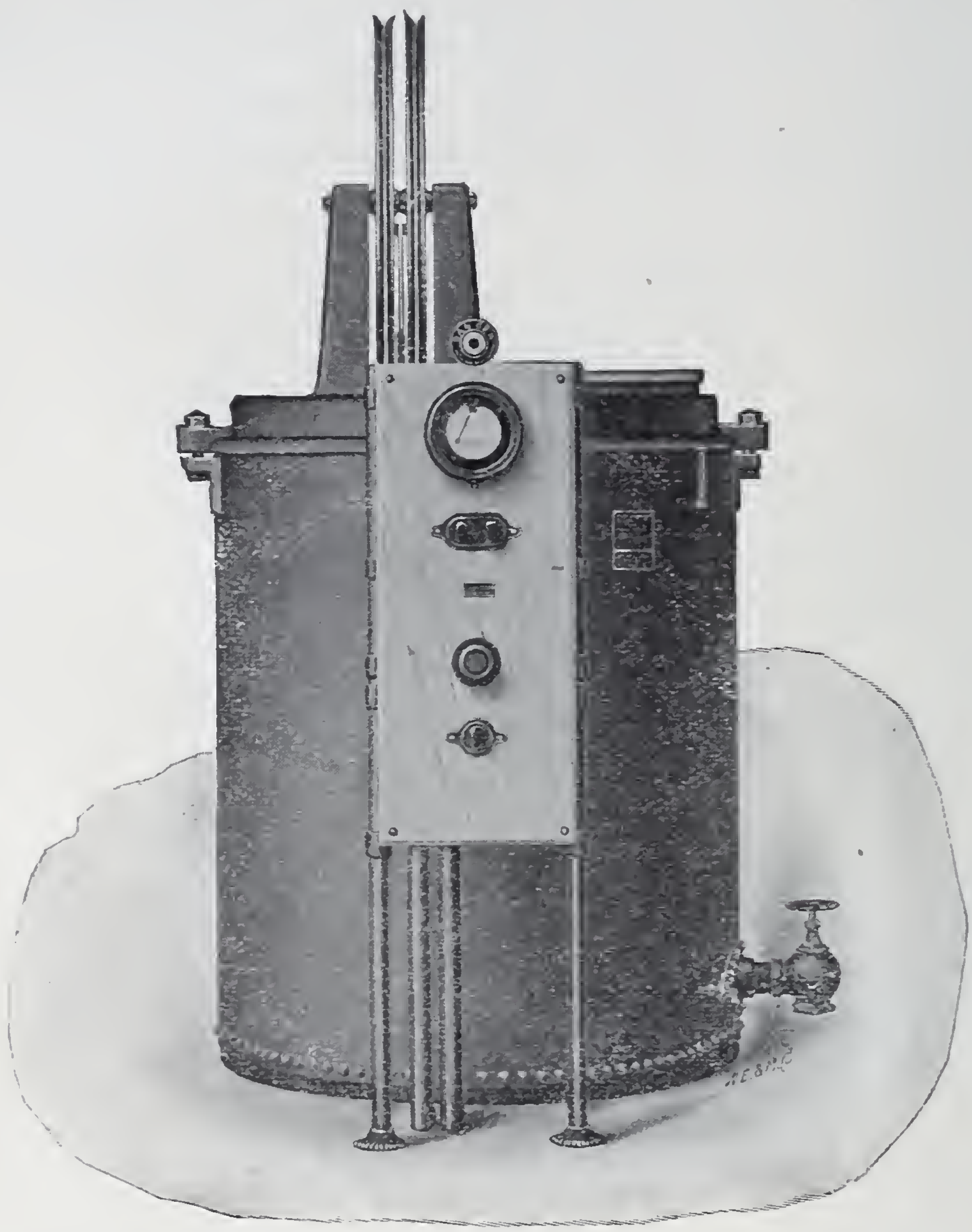

FIG. 9

until the current from the other has begun to flow. By giving certain values to this energy storing reactance, a certain shape can be given to the "ripple" in the D. C. wave. As the current is reduced the ripple remains the same, but its average height becomes lower. When the current becomes so low that the points of the ripple reach zero, the rectifier will drop

out or cease to operate as the negative electrode resistance has been re-established. This ripple can, if necessary, be made very small, but at some loss in efficiency. It is exceedingly difficult, however, to reduce the direct current value below two amperes, on account of the tendency of the negative electrode resistance to re-assert itself and stop the current altogether.

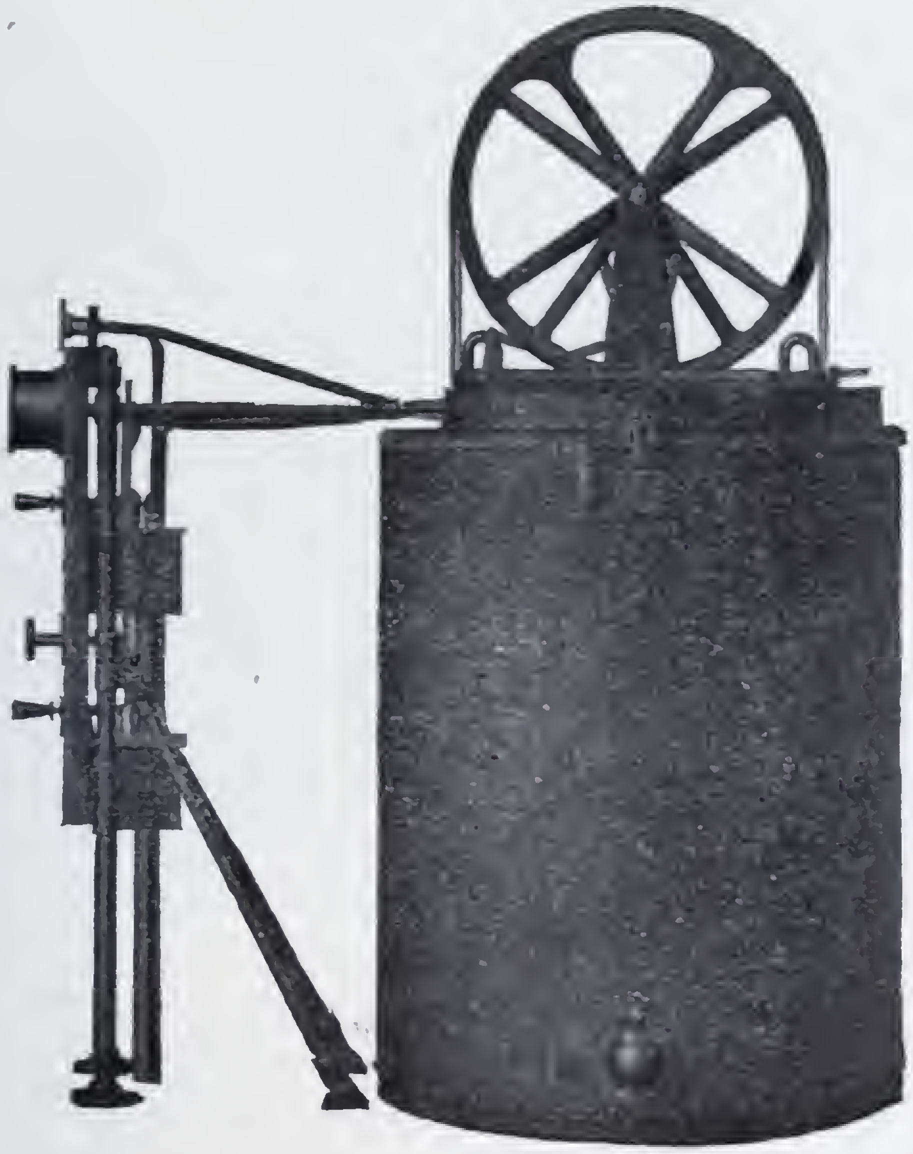

FIG. 10

The current passes through the vapor in the bulb in a diffused path, causing a general glow and this glow continues up to and around the anodes or positive electrodes. At the cathode, however, the current finds its way through at one small spot of great brightness. This spot is continually dancing around over the surface of the mercury, keeping that surface constantly agitated. Solid materials flash and give off sparks if by accident they become negative, and the mercury glows

over its whole surface if it is used as a positive electrode so their entrance and exit characteristics are determined by the direction of flow of current and not by the materials composing the electrodes.

APPLICATIONS OF THE MERCURY RECTIFIER.

At present the two principal uses for the mercury rectifier are for delivering direct current to constant current series arc lamps, especially those of the metallic flame type, and for battery charging. In either case there is no objection to the somewhat pulsating nature of the direct current.

For series arc lighting a constant current regulator similar to that used with the ordinary A. C. constant current system is required. Fig. 8 shows the typical connections. The primary coils of this regulator are movable and counter-balance each other in such a way as to give a constant secondary current. The small starting transformer is provided, simply to produce a spark for breaking down the negative electrode resistance in one of the mercury pools. Figs. 9 and 10 show the external appearance of such an outfit combined with its panel containing switches, ammeter, tilting handle, etc. The rectifier bulb is contained in a box, shown in Fig. 11, which may be slid down in guides into the case, or tank, until the buttons on the bottom make contact with similar buttons on the soapstone base. The bulb, therefore, runs in the same oil as the regulator, both for convenience in shortening up the high voltage wiring and to get the greater and more uniform cooling effect of the oil. Such arc light outfits are built in sizes from 25 to 75 lights in a single circuit and 100 lights if composed of two separate arc circuits.

For so-called low voltage purposes the mercury rectifier has its widest application to charging automobile batteries from the lighting service circuits. There is also considerable employment of rectifiers in charging the batteries of telephone substations and the batteries on Pullman cars for lighting purposes. Use is also found for them in delivering direct current to the hand fed arc lamp of moving picture ma-

chines. Figs. 12 and 13 show an ordinary panel type outfit for battery charging, capable of delivering seven to thirty amperes to batteries of from 10 to 44 cells. Very few vehicle batteries have more than 44 cells, as that is about the maximum number that can be charged from an ordinary 110 volt direct current circuit. There is no reason why batteries of a larger number of cells should not be used if desired, however, as a rectifier could readily be made to charge 100 or 200 cells and a smaller current would be required in charging a battery of a given power storage capacity.

FIG. 11

In charging automobile batteries it is often convenient to start the rectifier and be able to go away and leave it, permitting the charge to be completed without further attention. This can be accomplished by incorporating just the right proportion of reactance with the auto-transformer for each direct current voltage to give the proper drooping regulation curve to the outfit. Figs. 14, 15 and 16 show such an outfit for battery charging. The various direct current voltages are obtained by the proper dial settings as given by a table covering all the even numbers of cells within the range of a given outfit. If for a certain number of cells the dial setting gives 30 amperes at 2.1 volts per cell, the current will gradually taper down in value to about ten amperes at 2.5 volts per cell and at 2.55 volts per cell the current will be six to seven amperes and the rectifier will drop out or cease charging. This drooping characteristic is not obtained by the use of resistance, which would consume energy, but by reactance which simply slightly reduces the power factor. On account

of the characteristic of the rectifier, which permits the negative resistance of the cathode, or negative electrode, to reestablish itself after even an extremely short interruption of current, the rectifier will of course cease to operate if power is cut off the primary circuit even for the shortest possible interval. Where such an interruption is not likely to happen it is of no consequence, but where it is liable to occur, an automatic bulb tilting device can be provided which will cause the bulb to restart at all currents above 10 amperes, except when the dropping out is the result of the current be-

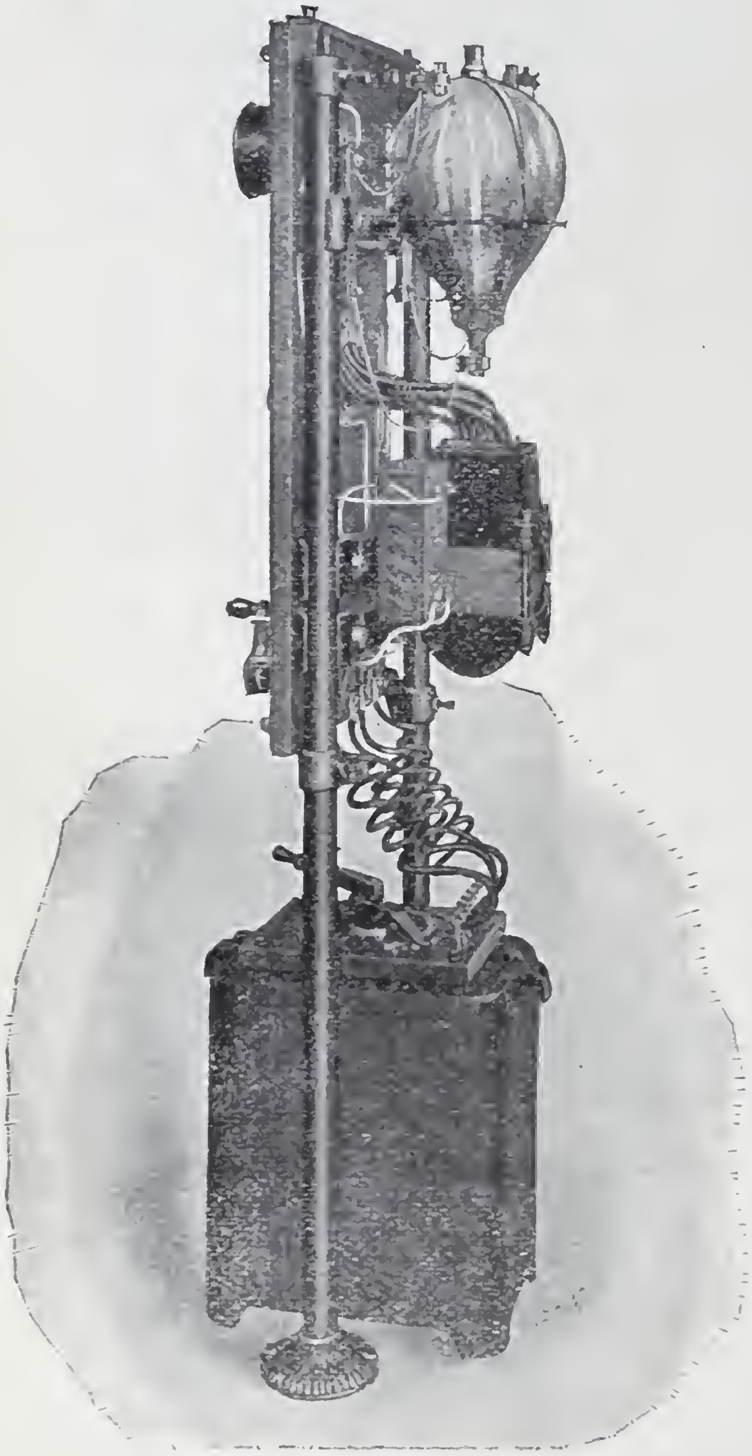

FIG. 12

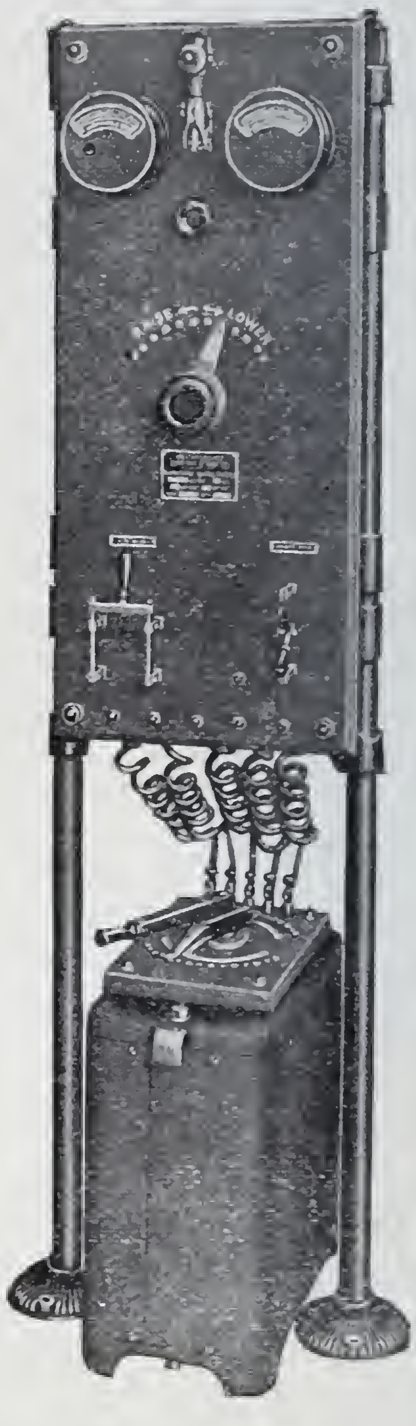

FIG. 13

coming low at the end of the charge when the battery voltage has risen to a maximum. About fifty amperes capacity is as large as seems to be practicable in a single rectifier bulb, but there is no particular difficulty in paralleling two or more bulbs if each individual circuit is ballasted properly, to make the bulbs divide the load. A rectifier bulb has characteristics similar to an arc, and it is well known that two arcs cannot be made to run in parallel unless ballasted by resistance, or reactance, to make the voltage over each arc circuit increase with an increase of current and vice versa.

FIG. 14

For telephone battery charging, the ripple or pulsating shape of the direct current must be reduced to such a degree as will prevent noise from being introduced into the telephone circuits. This is readily accomplished but requires various amounts of reactance in different telephone circuits. The reactance required also depends somewhat on the wave shapes of the generator supplying power.

Rectifiers are also made to supply direct current to the hand fed arc lamps of moving picture machines. For such purposes all that is necessary is to close the carbons together and the rectifier starts automatically. The arc may be pulled out to suitable length, if the carbons are pulled far enough apart the arc will break and the rectifier cease to operate.

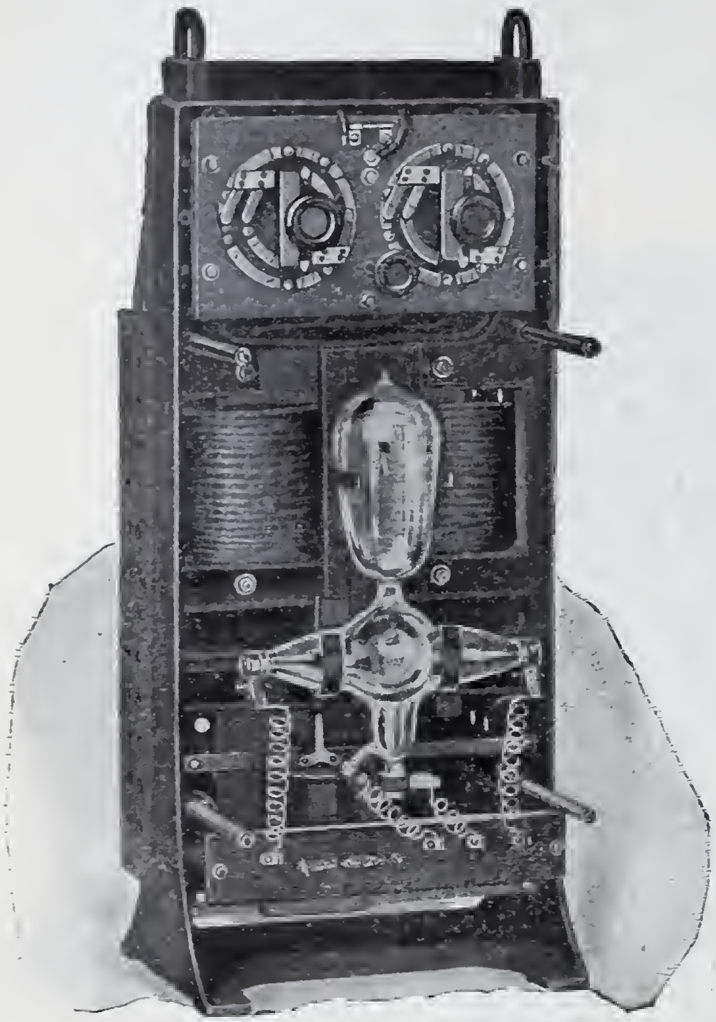

FIG 15

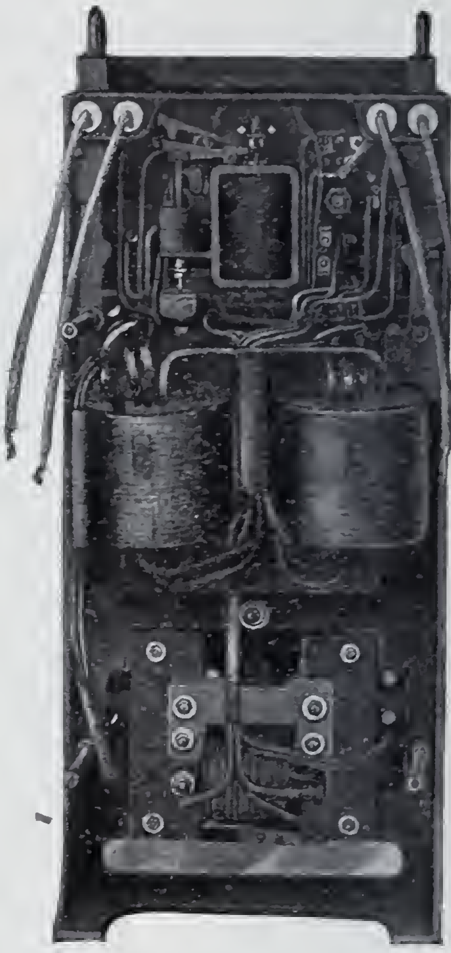

FIG. 16

The life of the rectifier bulb is a matter of much interest to users of rectifiers and is, moreover, a matter on which definite information cannot be given. A great deal depends on the usage a bulb receives and also on the quality of workmanship in its construction. There seems to be no reason why a good bulb should not run within its rating for 3 000 to 4 000 hours. While some bulbs do reach such a life the methods of production are not sufficiently uniform to make the average bulb last nearly so long. Six or eight hundred hours is a good average life at present, though there should

be no difficulty in finding some bulbs to run much longer. The actual final limit seems to be the disintegration of the glass by the long continued exposure to heat.

Unless supplanted by something still simpler and more reliable, the mercury rectifier will undoubtedly cover a wide field in supplying power in small units from A. C. circuits to those requiring direct current. Before it can be made applicable to currents of 100 amperes or larger from a single unit, however, some very difficult problems will have to be worked out.

DISCUSSION.

Mr. S. M. Kintner: I regret that I missed the early part of Mr. Jackson's paper and consequently do not know what he said on the general subject of rectifiers. At the risk of repetition I shall discuss, quite briefly, the principal methods of rectifying alternating currents, and indicate some of the more important uses to which such currents are put.

The rotation of a coil of wire in a magnetic field produces a voltage in the wire which is alternating in direction. If, however, this wire is connected to some form of switching device which interchanges the connections of the wire with regard to the external circuit at the instant of voltage reversal, the current that flows through the external circuit will be unidirectional, while that in the generating coil will be alternating. In the commercial generation of direct current, use is made of just such a switching device as that indicated above. This device is known as a commutator and serves the purpose of rectifying alternating currents. There are certain phenomena involved in the commutation of currents which makes it necessary to have the magnetic field present in order to commutate successfully any large currents. This fact makes the use of a commutator, driven synchronously as a rectifier, not feasible. It becomes necessary, therefore, in the commercial application of this particular principle of rectification, to use one of the two following methods:

1st. An alternating current motor driving a direct current generator.

2nd. A rotary converter, which is a combining of the motor and generator just mentioned into one machine. The rotary converter is in reality a direct current generator with special connections made to its windings for admitting the alternating currents to be rectified.

The principal point to be noted, however, is that both methods involve the use of revolving members which of course require bearings, control apparatus, attendance, etc.

The use of an electrolytic device as a rectifier has met with some success on a very small scale. In this apparatus terminals, such as aluminum and carbon, are immersed in a solution and these have the peculiar property of allowing current to pass through the solution from one terminal to the other much more readily in one direction than the other. With such a valve or trap like action it becomes possible to arrange the circuits so that both halves of the waves are utilized and efficiencies of 60 or 70 per cent are readily obtained. Such a device is quite sensitive and is not very satisfactory for large sized units.

The other type of rectifier which has met with commercial success is that described by Mr. Jackson tonight. The fact that the two latter types require so little attendance is the strong point in their favor.

There are two general uses to which rectified alternating currents from the last two types of rectifiers are put. These are for storage battery charging and arc light service. The rectified currents from this class of rectifiers are pulsating in nature and are not good for electroplating work. These pulsations are also not so good for service on which ordinary direct current motors are operating, although if designed for the service the conditions can be controlled sufficiently to allow satisfactory operation.

If rectifiers of the first type described, i. e., motor generators or rotaries, are used the rectified current can be used for

any purpose to which an ordinary direct current would be applied.

I would like to ask Mr. Jackson what efficiencies he is getting with these converters at the present day. My understanding is that it requires a constant voltage of approximately 20 volts regardless of the current taken from the converter.

The Author: It is true that an approximately constant voltage is taken by the rectifier, but it is not necessarily 20 volts. As stated in my paper, the voltage depends on the shape of the bulb and the distance between the positive electrodes and the negative. It may be as low as about ten volts, if the positives are comparatively close to the negative and the path is large and wide; but in the ordinary bulb used for battery charging it runs from 14 to 18 volts. This limits the efficiency and makes it dependent on the D. C. voltage being delivered. For instance if 100 volts are being delivered an effective voltage of about 120 must be put in, or if 80 volts are being delivered about 100 volts must be put in, which limits the efficiency to not over 80 per cent in this particular case. Again, with a bulb having a drop of 15 volts it is necessary to provide 35 volts to deliver 20, which is a comparatively low efficiency. The actual efficiency of a battery charging outfit ranging from 30 to 40 cells may be about 75 to 80 per cent. If the battery has only 10 to 25 cells the efficiency will be between 50 and 70 per cent. Of course as the delivered voltage is lowered the efficiency goes down, finally reaching an efficiency of zero on short circuit with the machine still running. With arc light outfits the bulb drop is insignificant compared to the total delivered voltage, in which case the efficiency, which is somewhat over 90 per cent is not controlled by the bulb at all, but is controlled by other things, such as the transformer.

Mr. S. A. Taylor: What occurs when charging cells from electric light wires supposed to carry 110 volts, but which in actual test by the volt meter show only 100 volts,

in other words under what variation of voltage is your apparatus capable of being worked successfully?

The Author: A battery charging set is designed for 110 or 220 volts and will deliver its rated direct current voltage; it is understood, however, to be capable of running on as low voltages as 100 or 200, and still deliver its rated voltage. Of course if the voltage goes below that, one could cover the lower ranges, but might not be able to reach the higher points. For instance, a 20 or 24 cell outfit with 110 or 220 volts supply is capable of charging from 20 to 44 cells while as a matter of fact if full voltage is given one might charge as high as 52 or 53 cells. In other words, the primary voltage might drop to 100 or 200, and the outfit still charge 44 cells. If the voltage should drop below that its capacity would not be over 40 cells, and if the voltage dropped still lower it would charge only 35 cells. But with the full drop to 100 or 200 volts the apparatus would still keep within the rated range.

Mr. S. M. Kintner: I think you did not get the point of Mr, Taylor's question. Assuming that the voltage drops after you make connection to a particular number of cells, would the rectifier fall out of action, or if not, what range of voltage could be allowed without adjustment?

The Author: That cannot be answered definitely. The rate of drop would depend on what the load happened to be. If it were a resistance load it would drop lower than if it were a battery. The difference between the resistance load and the battery is the counter electro-motive force. When the current in the battery comes down to somewhere between 5 and 7 the outfit would drop out. In general it would depend on how near the battery was to being fully charged. If it were nearly charged a very little drop would cause it to go out. If starting to charge the voltage might drop 10 per cent or more without going out. When it does go out, it will go out through a very slight drop in voltage, ½ to 1 per cent, when it is running at say six amperes, and a drop in current to even 5½ will put it out.

Mr. S. B. Ely: How often does this apparatus have to be inspected to see that it is in proper working order?

The Author: The battery charging set requires no inspection until the bulb finally goes out. When the apparatus does not work another rectifier bulb must be put in. After being properly connected, there is practically no attention required. There is nothing to deteriorate any more than in a service transformer. The arc light outfits require starting and stopping night and morning.

Mr. S. B. Ely: How much less trouble are they than the ordinary rotary converter of similar size?

The Author: The difference is that there is no commutator, no bearings to oil, and there is nothing that can go wrong with it to cause destruction. The worst thing that can happen, is the failure of the bulb. There are no moving parts, no friction of any kind, everything is static, and there is nothing to deteriorate outside of the bulb itself, which of course has a limited life.

Mr. S. M. Kintner: I was interested in some figures a friend of mine gave me a few days ago who has a rectifier in use for charging the battery of his automobile, a runabout. He stated that he was able to charge his battery sufficiently to give 30 miles service around the city streets at an expense of 25c to 30c. He obtained current from the lighting company at a special rate with the agreement to do his charging during the period of light load in day time. In comparison with gasoline you can see there is considerable difference in favor of the electric machine. With gasoline the best that can be done is 12 to 15 miles on a gallon of gasoline, which costs about 17c. I would like to ask about the parallel operation of these rectifiers for larger currents. Will they operate satisfactorily in parallel and divide the load without introducing any uncertain elements by the parallel operation, and is it possible to rectify in this way considerably larger amounts of energy in a satisfactory manner?

The Author: As I stated in the paper, they will parallel, but as they are ordinarily made with the sustaining power in

the auto-transformer itself and not in the separate coils, they do not parallel naturally. They require something in the direct current circuit, which may be an ordinary reactance coil, so that if one bulb tends to go out the stored energy is called upon to maintain the current. There is no particular difficulty in getting them started. They have the characteristics of arcs, that is one robs the other and one goes out unless each circuit has some regulation. Sometimes panels are put in with two bulbs for delivering 60 amperes. There is not very much demand for anything larger than 60 amperes. A 90 to 120 ampere outfit can be put up when there is call for it. If some other type of bulb is developed and becomes successful, it might have a limit of 100 or 150 amperes, and it may be practicable then to parallel them for larger capacities.

Before the Mechanical Section, October 6, 1908.

Chairman G. E. Flanagan

Presiding.

STRENGTH OF CONCRETE JOINTS.

By Joshua L. Miner,

Non-Member.

An important feature in monolithic concrete construction that has elicited some discussion, but on which little has been published beyond the opinions of various authorities, is the strength of the adhesion, or bond, of new concrete to old. It is quite often impossible for a foreman to finish, for causes unforeseen, a unit or predetermined amount of concreting in a single day. In large pieces of work it is seldom that concreting continues night and day, obtaining a solid mass of concrete, but in almost every piece of work fresh concrete is joined to concrete that has already set or hardened. Every engineer, contractor and foreman has his own methods for joining new concrete to old. For the purpose of determining the comparative strengths of these different joints, the following series of tests were undertaken at the laboratories of Lafayette College, and the results are given in the following pages. In this work I have been assisted by Messrs. Spengler and Walters of the present senior class in the Department of Civil Engineering. The following kinds of joints were tested:

B—Dovetail joints
C—Vertical joints roughened with cold chisel
D—Reinforced vertical joints
E—Scarf joints
F—Scarf joints scrubbed with oxalic acid
G—Scarf joints scrubbed with oxalic acid and treated with a paste of neat cement
H—Half and half or step joints

The reinforced vertical joints were reinforced with two $\frac{3}{4}$ in. round iron bars, 18 in. long with nuts at either end. These bars were placed $1\frac{1}{2}$ in. from the bottom and 2 in. from either side. The scarf joints were one-third the length of the beam and the step joints were 18 in. long. The end of the male part of the dovetail joint was 4 in. thick and the neck 3 in. thick.

FIG. 1

All beams were broken at the end of two months. The idea was not to determine the strength of these joints at the age of two months, but rather to determine their relative value when compared with each other, or to a solid beam of the same material. In the case of the gravel beams, those beams having scarf joints were found to be stronger than the solid beams. The explanation that is offered for this freak is that these beams were made in different forms than the rest of the beams. These forms were of exactly the same dimensions as the others, but of different construction, and it was found to be quite difficult to remove the beams from these forms

without injury, for which reason they were not used for any other specimens. This irregularity, however, does not materially effect the final conclusions.

All tests were made in triplicate and the average results taken except where the breaking load of one beam was so radically different from the other two that there was a doubt as to its value. In this case the average result of the two beams most closely agreeing was accepted.

The ends and sides of the forms were made of 2 in. by 10 in. rough hemlock boards. The side pieces were held in place by cleats on the end pieces and also by iron straps and bolts. The end pieces were fastened by hooks and eyes to the sides. Wooden pallets made of 1 in. by 8 in. spruce boards, cleated to raise them one inch above the ground, were fitted inside of the forms and served as the bottoms. The surfaces of these forms were neither shellaced or oiled and received no treatment other than that they were thoroughly wetted immediately before use. Fig. 1 gives a good idea of the simplicity of these forms and the ease with which they may be taken apart.

MATERIALS.

Crushed Rock No. 1.—Dolomitic limestone passing 1¼ in. and retained on a ¼ in. screen.

Crushed Rock No. 2.—Dolomitic limestone passing 1½ in. and retained on a ¼ in. screen.

Gravel.—Obtained from a gravel pit along the Delaware river above Easton. All of it passed a 2¼ in. screen and was retained on $\frac{1}{10}$ in. screen.

Sand.—Bank sand, clean and sharp, grading from ¼ in. to dust.

Crushed Screenings.—Obtained from crushed rock No. 2.

Cement.—Alpha Portland. This cement, which successfully passed the specifications of the American Society for Testing Materials, both when manufactured and when used, had been stored in the concrete laboratory nearly four months before these tests were undertaken, which accounts for the

generally low results that were obtained. Beams of the same dimensions and made with Crushed Rock No. 1, sand and the same cement when fresh, broke 30 per cent higher at half the age of similar beams in this investigation; but they were also stored in an immersion tank.

PROPORTIONING.

All proportions of the aggregates were determined from mechanical analyses as described by Messrs. Thompson and Fuller in their report on the series of tests conducted on the materials used in the construction of the Jerome Park Reservoir. This method, as published in the Transactions of the American Society of Civil Engineers, Volume 59, consists in plotting fineness curves for the materials to be used, each of whose ordinates represents the percentage of weight of the total sample which passes a sieve having holes of a diameter represented by the abscissae. These curves are then combined so that the resultant curve will approach as nearly as possible a parabola, which begins at the origin of the co-ordinates and ends at the intersection of the ordinate of the diameter of the largest particle and the 100 per cent line. The results given in Figs. 2, 3 and 4, represent the average of the materials analyzed and determined from 50 lb. samples. These samples were so taken as to fairly represent the materials. Fig. 2 shows the mechanical analyses of Crushed Rock No. 1, sand and the mixture of these materials. Fig. 3, the mechanical analyses of Crushed Rock No. 2, crushed screenings and the mixture of these materials, and Fig. 4, the mechanical analyses of gravel, sand and the mixture of these materials.

To five parts of the aggregate by weight was added one part of cement. The finer particles of the aggregate were not replaced by the cement as is sometimes done. This of course increased the percentage of the finer particles in the final mix. All proportions were made by weight, no allowance being made for moisture, as several tests showed that the small

amount present was fairly constant and in no case did it exceed 4 per cent.

All mixing was done by hand on a concrete floor. The weighed stone was spread evenly about six inches deep, and thoroughly moistened, the sand and cement, mixed to an even color, were spread over the stone. The materials were turned six times; twice dry, then with a little water added

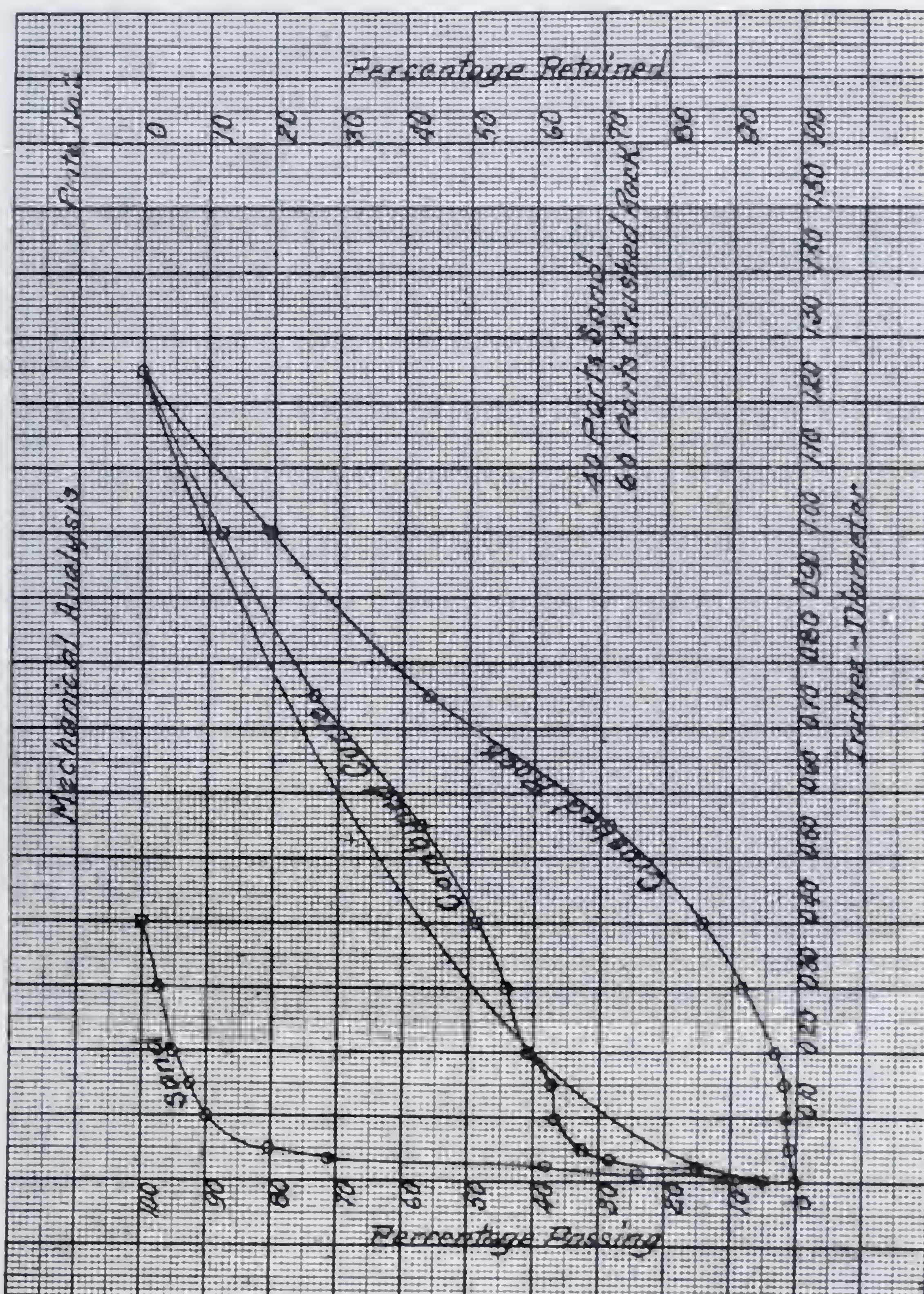

FIG. 2

from a sprinkler, more water being used during the last three turnings to obtain the desired consistency. Care was exercised in turning, to avoid heaping the concrete, thus preventing the coarser particles from rolling to the edges. Sufficient concrete was mixed at one time to make three whole beams.

The amount of water to be used was left to the judgment

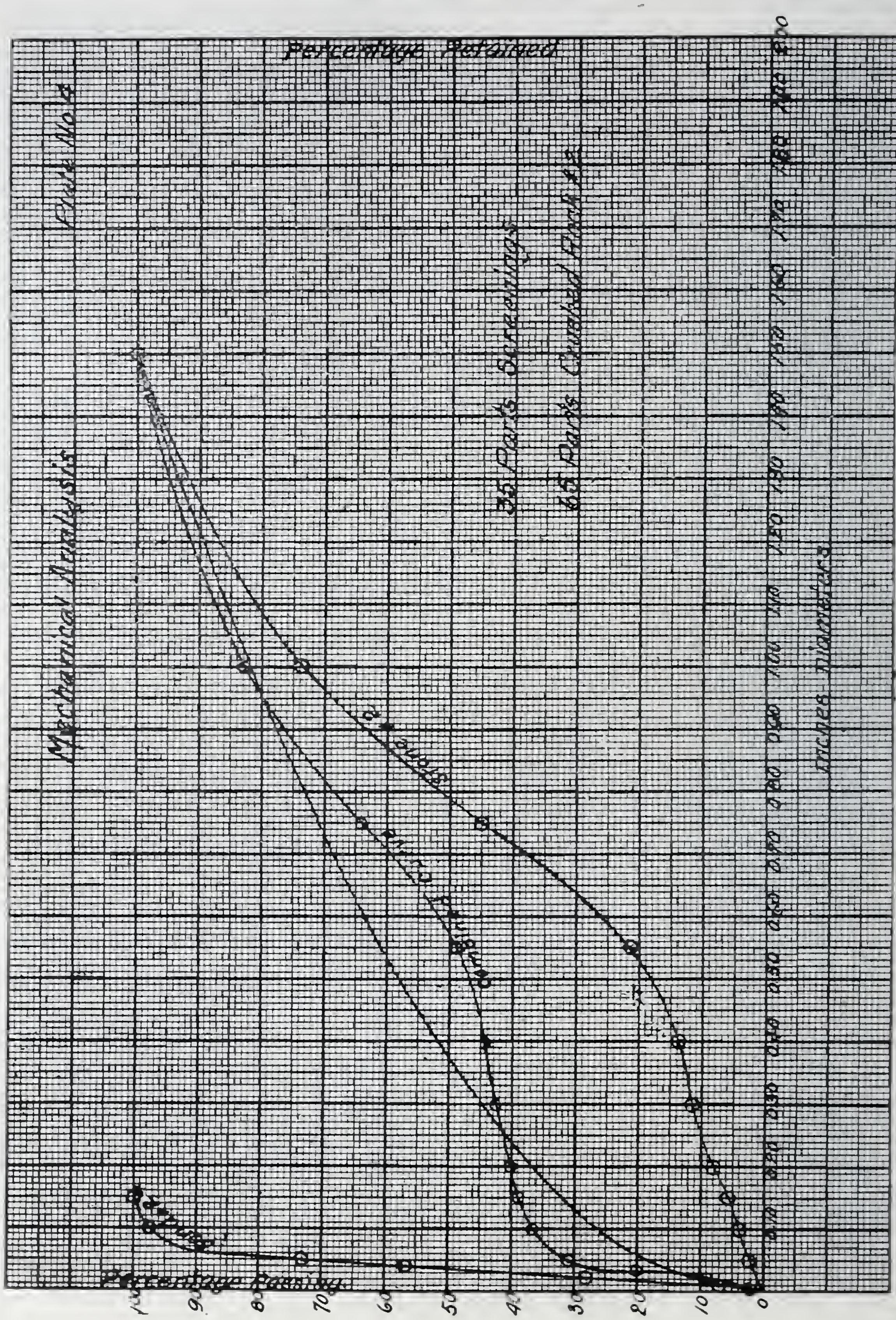

FIG. 3

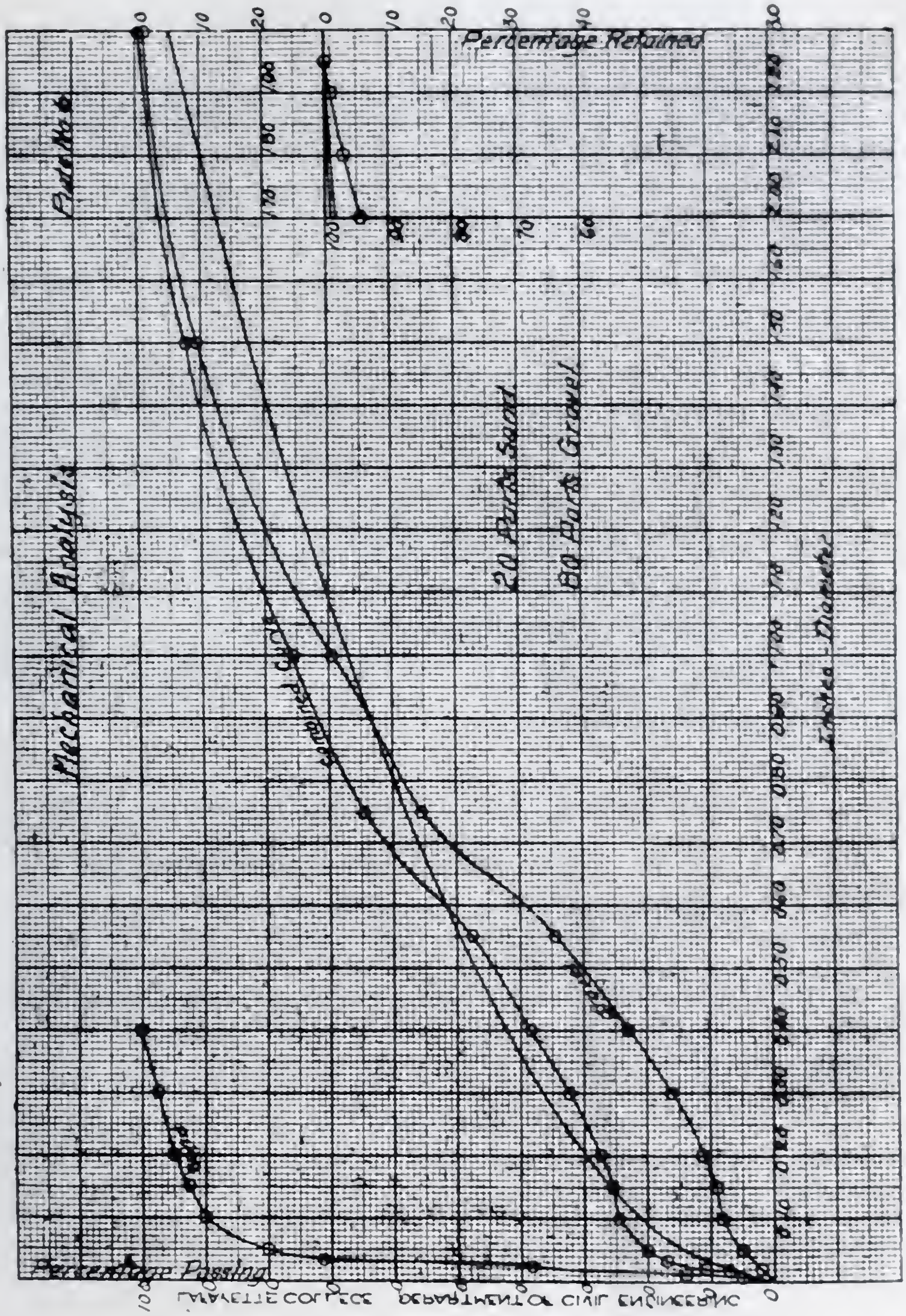

FIG. 4

of the operators. It was desired, however, to obtain a concrete of medium consistency that would quake easily like jelly, when disturbed. This was found from previous experiments to give not only the densest, but generally the most uniform concrete. The amount of water used did not vary more than 1 per cent either way in any of the mixtures of the same materials.

The concrete was shoveled into the forms and thorough-

ly rammed, with a ¾ in. round iron bar about 30 inches long, having a nut on the end, while being placed. At all times it was the aim to work uniformly in the preparation and testing of the specimens so that all errors or differences that might be caused by the personal equation could be eliminated or made constant.

The first half of all specimens were allowed to set 48 hours before the remainder of the beam was added. The forms were not removed until the completed beam was 48 hours old. The beams were not moved nor were they removed from their pallets until they were at least a week old. The concrete laboratory where the specimens were mixed, stored and tested, was of constant temperature, about 60 deg. Fahr., and somewhat damp so it was not considered necessary to guard against the specimens drying out too rapidly.

The beams were tested under a transverse load over a five foot span, the load being applied one foot each way from the center of the span. A 200 000 lb. Riehle testing machine was used. Resting on the V blocks which supported the beam was a wooden frame, which cleared the beam. This frame extended along both sides of the beam and midway between its supports were fastened two dial test gauges, which read to one thousandth of an inch. Strapped to the sides of the beam, midway between the V blocks, were two brass rods, which supported two adjustable arms. At the ends of these arms were set screws bearing against the contact points of the dials. As the beam deflected the arms released the contact points and the deflection was thus indicated on the dial. This arrangement gave two readings, one for either side, and the average of these results gave the mean deflection of the beam at the center of the span for each reading.

The load was applied in increments of 200 lbs. and the deflection noted each time. The apparatus for measuring the deflection of the beam, was designed by Prof. J. M. Porter, Dean of the Civil Engineering Department at Lafayette Col-

lege. In Fig. 5 are shown sketches of the various joints tested, and the location of the fractures in the broken beams.

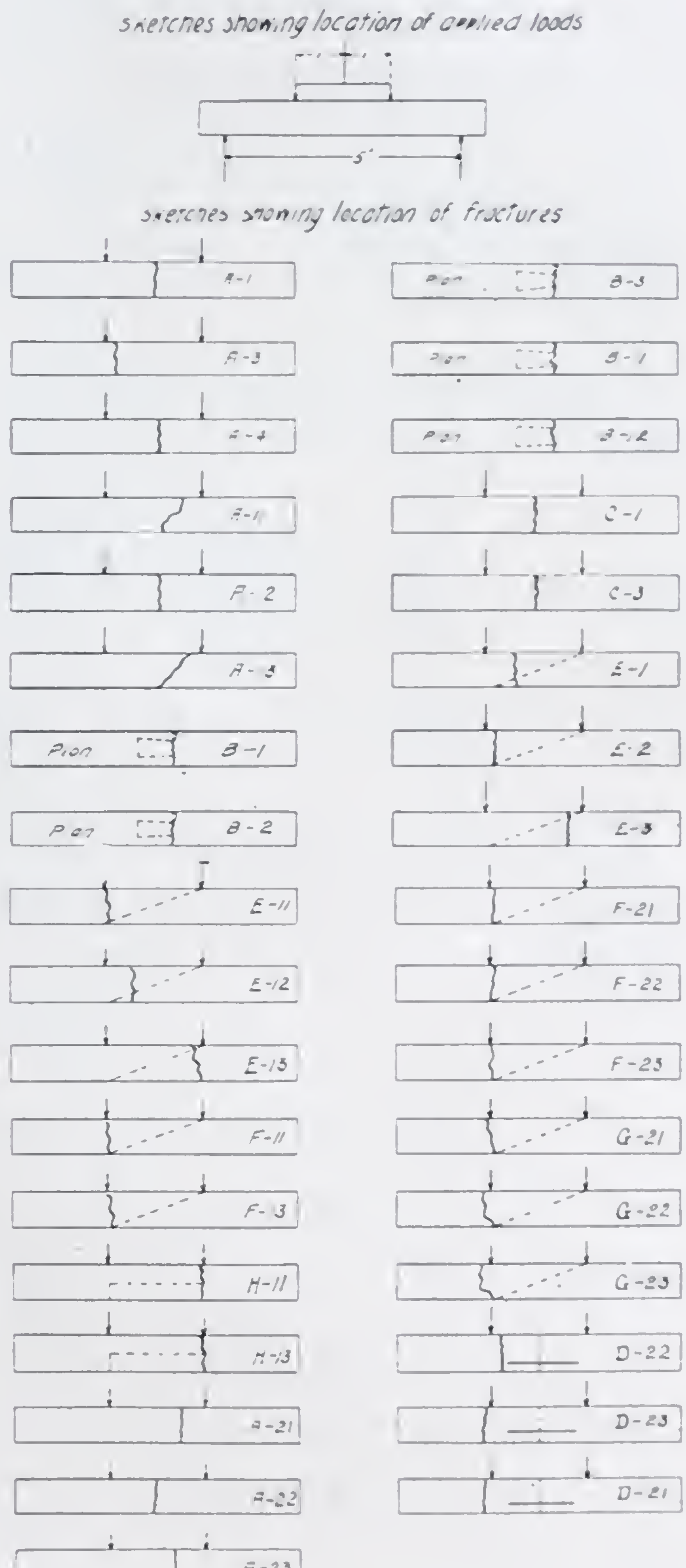

FIG. 5

GENERAL DATA.

FOR MEDIUM CONSISTENCY.

Crushed Stone No. 1, sand and cement required 8% water.

Crushed Stone No. 2, crusher screenings and cement required 10% water.

Gravel, sand and cement required 7.5% water.

	lb per cubic foot
Sand	100
Crusher screenings	110
Crushed stone No. 1	85
Crushed stone No. 2	96
Gravel	116

Each beam contained 2.66 cu. ft. and required the following quantities of materials:

	lb		lb
Crushed stone No. 1	232	Crushed stone No. 2	255
Sand	154	Crusher screenings	137
Cement	77	Cement	78
Water	37	Water	47
Total	500	Total	517

	lb
Gravel	308
Sand	77
Cement	77
Water	35
Total	497

RESULTS.

BEAMS OF CRUSHED STONE NO. 1 AND SAND.

Series A—Solid Beams.

Beam *A*-1. Discarded as the breaking load, 2200 lb., was too low. Modulus of rupture, 232 lb.

Beam *A*-2. Injured while hardening and was not tested.

Beam *A*-3. Failed near one of the applied loads at 3100 lb. Modulus of rupture, 327 lb.

Beam *A*-4. Failed at the center at 3450 lb. Modulus of rupture, 364 lb.

Average results for series: { Breaking load, 3275 lb.
Modulus of rupture, 345 lb.

Series B—Dovetail Joints.

Beam *B*-1. Failed at neck of male half of joint at 1400 lb. Modulus of rupture, 147 lb.

Beam *B*-2. Failed at neck of male half of joint at 1900 lb. Modulus of rupture, 200 lb.

Beam *B*-3. Failed at neck of male half of joint at 1800 lb. Modulus of rupture, 189 lb.

Average results for series: $\begin{cases}\text{Breaking load, 1700 lb.}\\ \text{Modulus of rupture, 178 lb.}\end{cases}$

Series C—Vertical Joints Roughened.

Beam *C*-1. Failed at the joint at 750 lb. Modulus of rupture, 79 lb.

Beam *C*-2. Broke in handling.

Beam *C*-3. Failed at the joint at 1050 lb. Modulus of rupture, 110 lb.

Average results for series: $\begin{cases}\text{Breaking load, 900 lb.}\\ \text{Modulus of rupture, 94 lb.}\end{cases}$

Series E—Scarf Joints.

Beam *E*-1. Failed at least section of under half of joint at 2150 lb. Modulus of rupture, 226 lb.

Beam *E*-2. Failed at least section of under half of joint at 2300 lb. Modulus of rupture 242 lb.

Beam *E*-3. Failed at greatest section of under half of joint at 2450 lb. Modulus of rupture, 258 lb.

Average results for series: $\begin{cases}\text{Breaking load, 2300 lb.}\\ \text{Modulus of rupture, 242 lb.}\end{cases}$

BEAMS OF GRAVEL AND SAND.

Series A—Solid Beams.

These were the solid beams that broke under a smaller load than Scarf Joint beams of the same materials.

Beam *A*-11. Failed with an irregular fracture slightly to right of center of beam at 1700 lb. Modulus of rupture, 179 lb.

Beam *A*-12. Failed midway between the applied loads. Result discarded, too low, at 950 lb. Modulus of rupture, 100 lb.

Beam *A*-13. Failed with a slanting fracture slightly to left of center of beam at 1850 lb. Modulus of rupture, 195 lb.

Average results for series: { Breaking load, 1775 lb.
Modulus of rupture, 187 lb.

Series B—Dovetail Joints.

Beam *B*-11. Failed at neck of male part of joint at 1350 lb. Modulus of rupture, 142 lb.

Beam *B*-12. Failed at neck of male part of joint at 1350 lb. Modulus of rupture, 142 lb.

Beam *B*-13. Was injured in handling and was not tested.

Average results for series: { Breaking load, 1350 lb.
Modulus of rupture, 142 lb.

Series E—Scarf Joints.

Beam *E*-11. Failed at least section of under half of joint at 1850 lb. Modulus of rupture, 195 lb.

Beam *E*-12. Failed at least section of under half of joint at 1900 lb. Modulus of rupture, 200 lb.

Beam *E*-13. Failed at greatest section of under half of joint at 1750 lb. Modulus of rupture, 185 lb.

Average results for series: { Breaking load, 1833 lb.
Modulus of rupture, 193 lb.

Series F—Scarf Joints Scrubbed with Oxalic Acid.

Beam *F*-11. Failed at least section of under half of joint at 2150 lb. Modulus of rupture, 226 lb.

Beam *F*-12. Was injured when removing forms and was not tested.

Beam *F*-13. Failed at least section of under half of joint at 2250 lb. Modulus of rupture, 237 lb.

Average results for series: { Breaking load, 2200 lb.
Modulus of rupture, 231 lb.

Series H—Half and Half Joints.

Beam *H*-11. Failed at lower vertical joint at 800 lb. Modulus of rupture, 84 lb.

Beam *H*-12. Failed at lower vertical joint at 550 lb. Modulus of rupture, 57 lb.

Beam *H*-13. Failed while being handled.

Average results for series: { Breaking load, 675 lb. Modulus of rupture, 70.

BEAMS OF CRUSHED STONE NO. 2 AND CRUSHER SCREENINGS.

Series A—Solid Beams.

Beam *A*-21. Breaking load 2900 lb. Modulus of rupture, 306 lb.

Beam *A*-22. Breaking load 3700 lb. Modulus of rupture, 390 lb.

Beam *A*-23. Breaking load 3000 lb. Modulus of rupture, 316 lb.

Average results for series: { Breaking load, 3200 lb. Modulus of rupture, 337 lb.

Series D—Vertical Joints Reinforced.

The reinforcement for these joints extended only nine inches either side of the joint. But it was sufficient to insure the beams against failure at the joint. The fracture occurred each time beyond the reinforcement and near one of the applied loads. After the tests on this series had been completed the sections of the beams containing the reinforced joints were retested. The span in this case was 17 inches or one inch less than the length of the reinforcement. The load was applied at the center of the span and directly at the joint. The fracture occurred in this instance near the end of the reinforcement and was caused primarily by the slipping of the iron and nut. The average breaking load of these beams was a few pounds greater than that of the solid beams; but the difference is so slight that it need not be considered. Further, this result should be expected as the fracture occurred beyond the reinforcement.

Beam *D*-21. Broke at 2900 lb. Modulus of rupture, 306 lb.
Beam *D*-22. Broke at 3100 lb. Modulus of rupture, 327 lb.
Beam *D*-23. Broke at 3700 lb. Modulus of rupture, 90 lb.

Average results for series: { Breaking load, 3233 lb. Modulus of rupture, 341 lb.

Series E—Scarf Joints Scrubbed with Oxalic Acid.

The average breaking load of these beams, as in the case of those made with gravel, was greater than that of the solid beams. The writer is at a loss to offer an acceptable explanation for these results. The difference in this case is not great and might be overlooked. All the beams failed at the least section of the under half of the beam or joint.

Beam *F*-21. Breaking load 3900 lb. Modulus of rupture, 411 lb.
Beam *F*-22. Breaking load 2900 lb. Modulus of rupture, 306 lb.
Beam *F*-23. Breaking load 3500 lb. Modulus of rupture, 369 lb.

Average results for series: { Breaking load, 3433 lb. Modulus of rupture, 362 lb.

Series G—Scarf Joints Scrubbed with Oxalic Acid and Treated with Paste of Neat Cement

The average results for this series are the same as those for solid beams, and only 233 lb. less than those scrubbed with the acid but not treated. It would seem from this that no real advantage is gained by treating the surface of the joint with paste of neat cement. Failure in all these beams occurred at the least section of the under half of the joint.

Beam *G*-21. Breaking load 3200 lb. Modulus of rupture, 337 lb.
Beam *G*-22. Breaking load 2700 lb. Modulus of rupture, 285 lb.
Beam *G*-23. Breaking load 3700 lb. Modulus of rupture, 390 lb.

Average results for series: { Breaking load, 3200 lb. Modulus of rupture, 337 lb.

Table 1 gives a recapitulation of the results obtained in this series of tests, showing the breaking loads.

BEAMS	STONE No. 1					GRAVEL					STONE No. 2				
	1	2	3	4	Average	11	12	13	14	Average	21	22	23	24	Average
Solid Beams.............. ....A	(2200)	*	3100	3450	3275	1700	(950)	1850	....	1775	2900	3700	3000	....	3200
Dovetail Joint............................B	(1400)	1900	1800	....	1700	1350	1350	*	....	1350	....	....	....	....	....
Vertical Joints, Roughened........C	750	*	1050	....	900	....	....	....	....	....	....	....	....	....	....
Vertical Joints, Reinforced........D	....	....	....	....	....	....	....	....	....	....	2900	3100	3700	....	3233
Scarf Joints...................... .....E	2150	2300	2450	....	2300	1850	1900	1750	....	1833	....	....	....	....	....
Scarf Joints, Washed Oxalic Acid..F	....	....	....	....	....	2150	*	2250	....	2200	3900	2900	3500	....	3433
Scarf Joints, Washed Cement.....G	....	....	....	....	....	....	....	....	....	....	3200	2700	3700	....	3200
Half and Half, or Step Joints.......H	....	....	....	....	....	800	550	*	....	675	....	....	....	....	....

* Beam injured and was not tested.

TABLE 1.

CONCLUSIONS.

The reinforced joint proved to be the strongest joint tested, failure occurring not at the joint but beyond the reinforcement. Of the different scarf joints, which were the next strongest, those scrubbed with oxalic acid were a little stronger than those not scrubbed. The treating of the surface of the joint with a paste of neat cement from the results of these tests, proves to be of but little value. The dovetail is the next strongest joint. This type of joint although stronger than the remaining kinds seems to be much weaker than the scarf joints. The vertical joints roughened and the half in half, or step joints, were the weakest of all those tested. In every case they gave a low breaking strength, frequently breaking while being handled.

DISCUSSION.

Mr. W. G. Wilkins: I would like to ask Mr. Miner if he has made any experiments with horizontal joints the whole length of a beam. I think that is a joint apt to be met with in concrete construction more than any of the joints you have spoken of. In making long concrete beams the first layer of concrete may set before you can put the next on, and that will make a joint.

The Author: I have not tested any joints of this sort but am glad to have the suggestion, as it is expected to carry on further tests this coming winter.

Mr. E. W. Pittman: On one of the slides under the head of gravel beams, if I saw correctly, the strength of the scarf joint washed with oxalic acid was higher than the solid beam.

The Author: That was the case not only with the scarf joint washed, but also with the scarf joint untreated. I am inclined to think we injured those solid beams in taking them out of the forms. In the regular forms the sides were held in place with straps and bolts, while in the other forms the sides were held in place by rigid uprights. We could not turn the beam in these forms on its side and knock off the bot-

tom, but we had to put a wedge under the beams and gradually lift them. If concrete is injured by striking a piece that is suspended or supported at two or more places, it will be weakened.

Mr. E. S. McClelland: I would like to know just what the object is in making a joint in a concrete beam? What is the necessity for it?

The Author: Of course no one would make a beam with a joint, especially in the center of it. These tests were not for the purpose of merely determining the strength of these joints; but in monolithic concrete work there are bound to be joints where fresh concrete is joined to old. From inquiries made of concrete contractors, I found they were using different methods of joining fresh concrete to old, and it seemed to me that testing these joints under a transverse load would be the simplest way to arrive at their comparative values.

Mr. Emil Gerber: I have been very much interested in Mr. Miner's experiments, and am glad to note that when it becomes necessary to make a joint in a concrete beam for any reason, that the scarf joint has some advantages over others. Of course, nobody wants to make a joint in a beam if it can be avoided, but sometimes it becomes necessary.

I would like to ask Mr. Miner why he threw out any of his results in geting an average. The inherent difficulty in concrete construction is the uncertainty of making the concrete of the same quality every time, due to carelessness of workmen in mixing, placing and ramming, and the erratic results which Mr. Miner has obtained and thrown out, emphasizes that very uncertainty. In his laboratory work he took particular pains to eliminate personal equation, yet under this careful treatment some of his joints did not hold together long enough to put the beam into the machine, and it seems to me that all tests should have been counted in making the average. When new concrete is placed on old concrete we do not know whether it will stick or not, and that uncertainty

ought to be taken into consideration in averaging the test results.

The Author: In throwing out a result I did not mean in any case to throw out the lowest, but the one that differed most widely from the others. I followed a rule used in a number of testing laboratories, where they accept the results that most closely agree. In some instances where five tests are made, the three or four that most closely agree are accepted. I would have discarded an unusually high result as quickly as a low one. But if all the results I discarded had been included in the averages, I do not think they would have affected the final results. The conclusions would have been practically the same.

I would like to ask the gentleman who suggested making an experimental beam in two sections, running the joint through from end to end, whether that joint should be put in the plane of the neutral axis?

Mr. W. G. Wilkins: Make it at different points, both above and below.

Mr. R. H. Stevens: Were the edges of the scarf joints brought down to a knife edge and did you make any tests of a scarf joint in a column carrying a direct load?

The Author: The scarf joints were brought down to a knife edge. We have some tests of these different joints in columns under way now. The test specimens are 8 in. in dimeter and 16 in. high.

Mr. W. G. Wilkins: May not the failure of some of these tests be caused by faulty manipulation?

The Author: That is the explanation that is generally made in throwing out results. The personal equation is a tremendous factor in testing cement and concrete, and is very hard to eliminate. It may have been that the man who was doing the ramming did not exert the same effort on the last beams that he did on the first. These are points that enter into any construction.

Mr. W. G. Wilkins: In the construction of concrete buildings, the inspection and supervision of the work are very

important factors. The very best grade of cement may be used, as well as clean, sharp sand and gravel, or broken stone, but unless the concrete is properly mixed and placed in the forms, there may be a weak spot, the result of which will mean disaster to part of or even the entire structure. With a steel structure, the materials are usually all tested in the shop, and all rivet holes for field erection, punched or drilled before shipment. In the erection of the steel work, while every rivet hole should have its rivet, the omission of a single rivet will not be likely to cause the failure of the structure; while in a concrete structure, a weak spot such as may result from imperfect joining of one day's work with that done on the previous day, may prove disastrous. For this reason it is exceedingly important to have proper and efficient supervision for concrete structures. It is not so long ago that the papers were full of accounts of the failure of a large reinforced concrete building with the loss of several lives. It developed at the coroner's inquest, that in one of the columns there was an absolute break in its continuity, owing to there having been a lot of shavings blown into the form during the night and which were not removed before the next day's work was begun. It also developed that the inspector employed by the owners had been a teamster with absolutely no knowledge of building or concrete work.

Another point in connection with reinforced concrete construction is the fact that some contractors design and construct work of this character, who have absolutely no knowledge of the proper scientific designing of the buildings which they construct, and have an idea that a few rods put in the concrete in almost any way constitute a reinforced concrete structure.

A certain large hotel at one of the seaside resorts was of reinforced concrete. The footings under some of the columns were six feet square, about two feet in thickness, and rested on wooden piles. In order to carry out the idea of reinforcing the concrete all through the structure, these concrete footings were reinforced (?) by two ¼ in. rods on each diagonal of the

footing and two similar rods across the middle of the footings. I merely mention this case to show the utterly unscientific methods of some reinforced concrete contractors and designers.

The Author: In the way of emphasizing Mr. Wilkins' remarks, I would refer to an article on "Cement Its Use and Abuse," by Robert W. Leslie, in the August, 1908, number of the Journal of the Franklin Institute, in which the author compares the inspection usually given steel and concrete building material. The raw materials entering into the steel member are carefully analyzed and the steel itself subjected to physical tests before the finished beam, girder or column, as building material, is passed. Before erecting, this finished member is rigidly inspected. Concrete building material, however, is rigidly inspected only in the cement itself which is perhaps but 1/7 of the materials entering into the manufacture of a concrete building element. The other materials are often accepted with only a cursory examination and the mixture made without any idea of the analysis of the materials. Further, the inspector is often selected on account of immediate availability from among the erecting force and not for his knowledge of the actual requirements in concrete construction. If the building fails the fault is immediately attributed to poor cement. Building records show that most of the failures in concrete occur at the time of construction and very few afterwards. The cement is often given credit for a good many things it does not deserve.

Mr. E. W. Pittman: In addition to the breaking load of each beam, Mr. Miner gave what he called the modulus of rupture, which seemed to vary between 70 and 200 lb. Was that obtained by dividing the bending moment by the section modulus of the beam? The reason I ask is because one of the results did not seem to be right, the one where the modulus of rupture was given as 70.

The Author: The mathematics were worked out by Mr. Spengler and Mr. Walter. They used the formulae in Johnson's Mechanics and Materials, and I believe the modulus of

rupture was figured as you state. I think all the results will check up pretty well because they were gone over by three persons working independently.

Mr. L. P. Blum: Regarding the elimination of the personal equation, I understood material was mixed at one time for three beams. Were the three beams cast at the same time, or was a solid beam, a portion of a scarf and a portion of a step joint beam made out of one mixture? The latter would seem to be one method of eliminating the personal equation.

The Author: What should have been done would have been to make all the beams at one time from one mix with an automatic rammer. We were handicapped for room and time, and six half beams were made from one mix. We would make say three scarf joint and three dovetail joint half beams one day, and two days later make the other halves. In making these halves we would make first a scarf, then a dovetail joint; next a scarf, then a dovetail, and so on, to make them as nearly uniform as possible.

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President James K. Lyons

In the Chair

THE CORROSION OF IRON AND STEEL

By Alfred Sang

THE DECAY OF IRON

The decay of iron and steel by corrosion, if natural agencies are allowed to act on them, is far more rapid than that of wood and other materials of construction. Steel is being used more and more every day for buildings and other permanent structures and therefore on the prevention of this decay depend the permanency of these works and the safety of future generations. Were it not for iron and steel, the erection of large works of engineering would be impossible and their very size and consequent high cost, representing as it does a large sum of human energy—which is after all the only true foundation for wealth—make it a duty to preserve them from decay.

On a structure like the Forth bridge, a number of men are kept at work, cleaning rust-spots and repainting. The wise course of preserving such structures for the use of our descendants is not generally followed, and it is only when accidents like the one at Charing Cross Station in London

take place, that interest is revived, for a time, in the question. Wood, in referring to the roof of a gas-works in New York City which collapsed for lack of attention, forecasted a similar fate sooner or later, for structures like the viaducts of the elevated railway of the same city, which almost casual observation will show are repainted *over* the rust without cleaning.

On account of this necessity of combating corrosion, it is imperative that engineers arrange the design so that every part of structural works be readily accessible for frequent inspection. It has been truly said that "wrought iron is not only a bad but a dangerous material if neglected"; this is equally true of steel.

COMPOSITION OF RUST

In order to bring about improvements in the protection of metals from corrosion, it is necessary to study the nature of this corrosion; to devise either preventives or cures the disease itself must be understood.

Rust is a hydrated ferrous sesquioxide ($Fe_2O_3.nH_2O$) of a brown, red-brown or yellow-brown color; when formed under water it is generally of a deeper tint and is of a somewhat colloidal nature. Rust formed under water in the presence of a small amount of acid, is partly colloidal or embedded in a colloidal matrix of uncertain composition; if the rusting is intensified by applying an electric current, the gelatinous nature of the deposit becomes evident; when formed slowly, it adheres very tenaciously in the unevennesses of the surface. Its composition varies within narrow limits; according to Toch, the rust nearest the iron is highly ferrous, blending outwardly into a more stable oxide; this is due to the progressive nature of the decomposition taking place; Andrews has shown that the *rate* of decomposition also increases progressively, being, under the conditions of his experiments, about 50 per cent more rapid the second year than the first. The inner portions of a coating of rust may also contain some ferrous carbonate.

Rust is not crystalline; it is granular and amorphous;

very ancient rust is, however, said to consist of a mixture of magnetic oxide and anhydrous sesquioxide in a more or less crystallized condition, not unlike the crystalline hematite, or oligistic iron, abundant in Elba, but also found in other iron-ore regions. It is also claimed that ammonia may be formed during rusting, as in the case of organic matter undergoing decomposition; Bloxam claims that ammonia is formed from the nitrogen of the air during the process of rusting.

FORMATION OF RUST

Under normal conditions, corrosion never seems to take place evenly; upon closer investigation it is found that it does not and cannot take place evenly; this is due to "pitting"; the rust commences to form at distinct points which must therefore be particularly liable to attack. The spreading of the rust from these original points is like that of a disease. There is a peculiar formation known as "tubercular corrosion" which owes its name to the wart-like concretions of rust and earthy matter derived from the water, which grow on the metal: this form of corrosion is specially frequent in cases where alkalies and saline matter are present together in a highly aerated water; it is common in water-mains. Rusting starts at certain points and spreads out until the different growths unite into a continuous covering. The theory of pitting, due to John, is that at the point where it takes place there is a speck of impurity, such as a particle of slag or scale, or a segregated constituent of the metal, which gives rise to galvanic action.

Corrosion by pitting may reach thru a plate long before the greater part of the surrounding surface is seriously rusted. Were corrosion to take place evenly, the life of the material would be greatly extended. In proof of this Mallet made a series of experiments (1); they were carried out on large surfaces and at ordinary temperatures over a long period of time; he found the following average relative depths of corrosion

(1) Trans. Inst. Nav. Arch. vol. XIII (1872), pp. 114, 115 and 116.

for one century of time for steel and wrought iron taken together:

In the atmosphere and freely exposed to the weather	0.0343	of an inch
In fresh river water	0.0352	" "
In clear open sea-water	0.3263	" "
In sewage-fouled sea-water	0.5327	" "

The tables of actual results with various grades of iron and steel which yielded the above averages are very instructive, altho the chemical compositions and physical conditions must in many, if not all, cases have differed from those of equivalent qualities manufactured nowadays.

Rust forms in layers which can be detached from each other and as it is more or less spongy, it will retain moisture in close proximity to the iron, besides giving rise to an unfavorable voltaic action. It also acts as a carrier for oxygen, furnishing it to the iron and replacing it from the air. These properties promote the growth of rust both laterally and in depth.

Rusting is the reversal of the process of iron smelting; the corrosion of iron to the sesquioxide must release the same number of calories as would be absorbed in converting a natural sesquioxide into iron.

As will be seen, while there is considerable doubt as to the necessity of an acid being present to cause rusting, there is no doubt whatever about its being essential that both oxygen and water be present; it is also claimed by some that the moisture must be able to *condense* on the surface of the metal. There are three theories of rusting and in examining them it it well to bear in mind that while one or other of them may explain the true *first cause* of rusting, the others may, and some of them undoubtedly do, present conditions which, if not essential, at least intensify the decomposition. A summary of theories has been published by Mugdan ([2]).

(2) Zts. f. Elektroch. vol. 9 (1903), p. 442.

CARBONIC ACID THEORY

The oldest of the plausible theories of corrosion, whose chief supporters have been Dr. F. Crace Calvert (3) and Gerald Moody (4), supposes that carbonic acid attacks the iron, converting it into a carbonate and releasing hydrogen which unites with the oxygen present, as air or otherwise, to decompose the ferrous carbonate to ferrous hydroxide, or rust, leaving the same amount of acid as was originally present to react as before and form more rust. The theory is a perfectly logical one. The objection that it is not proved that iron will rust in thoroly boiled distilled water is not insuperable. Stephane Leduc has shown that it is impossible to extract all of the dissolved gases from distilled water by boiling; he claims that not less than one cubic centimeter of gas would be left in one liter of water, which it is impossible to remove. Part of this gas must, almost certainly, be carbonic dioxide, of which there is 0.04 per cent present in the atmosphere; it is more soluble in water than the oxygen and nitrogen of the air.

The operation of rusting being, according to this theory, a cyclical or regenerative one, it has been argued (5) that a single molecule of carbonic dioxide would be sufficient to start and maintain corrosion in the presence of air and water. The carbonic acid, due to the combination of the carbonic dioxide with water, would, by its action, put iron into solution; this is all that is necessary to corrosion, the dissociated iron being oxidized to rust in the presence of oxygen. If, however, this residual gas in water cannot be removed by physical means, such as boiling, it may be feasible to do so chemically; even then it is possible that a definite degree of concentration of the acid neutralizer would have to exist; this would explain the rusting of iron in weak alkaline solutions.

(3) Mem. Litt. Phil. Soc. Manchester, vol. 5 (1871), p. 104; also Chem. News, Mar. 3, 1871.
(4) Proc. Chem. Soc., vol. 22 (1906), p. 101.
(5) J. N. Friend: Nature, May 14, 1908.

Dr. Allerton S. Cushman's careful experiments (6) seem to show, almost conclusively, that rusting will take place when there is no carbonic acid present; when there is, there is a greenish carbonate formed which promptly changes to the hydroxide when oxygen is supplied to it. On the other hand, while the carbonic acid theory may accurately describe how rusting does actualy take place under normal conditions, and be, therefore, correct, there seems to be little reason to doubt but that rusting can take place without its aid. This conclusion, based on the valuable work of Dr. Cushman, agrees with what Mallet wrote in 1872: "If the air contains vapour of water, however, chemical action rapidly occurs, more rapidly if carbonic acid also be present. The presence of the latter is, however, not necessary to initiate the action, as has been stated by Calvert."

HYDROGEN PEROXIDE THEORY

The second theory of rusting, originally due to Traube (7), is known as the peroxide theory. According to this theory, the iron, oxygen and water are supposed to react to form ferric oxide (Fe O) and hydrogen peroxide (H_2O_2), which then unite to form the ferrous hydroxide, leaving an excess of hydrogen peroxide which attacks a new quantity of iron.

It has been found impossible to detect the presence of hydrogen peroxide during rusting, and while this failure may not condemn the theory, it makes it appear improbable. Furthermore, both Moody and Cushman claim that iron does not rust in pure neutral hydrogen peroxide.

ELECTROLYTIC THEORY

The third and most widely accepted theory is the electrolytic one. When two substances of different polarity are immersed in a suitable electrolyte—or medium containing free ions of matter—an electric current is set up and the substance from which the current flows tends to dissolve. So far as corrosion is concerned, the theory implies the solution of the

(6) Bull. No. 30, U. S. Bur. Agric., July 23, 1907.
(7) Deuts. Chem. Gesell., vol. 18 (1881).

iron in water or moisture as ferrous ions; the iron, while in this dissociated condition, is oxidized by any free oxygen present. To quote Dr. Cushman (8): "If, therefore, we immerse a strip of iron in a solution *containing hydrogen ions* (9), iron will go into solution, and hydrogen will pass from the electrically charged or ionic to the atomic or gaseous condition. In such a system the solution of the iron and, therefore, its subsequent oxidation, must be accompanied by a 'precipitation' or setting free of hydrogen. It is very well known that solutions of ferrous salts as well as freshly precipitated ferrous hydroxide are rapidly oxidized by the free oxygen of the air to the ferric condition, so that if the electrolytic theory can account for the original solution of the iron the explanation of rusting becomes an exceedingly simple one."

It is erroneous to say that iron only corrodes *when anode*. Ordinary iron corrodes whatever the galvanic position of the mass may be in reference to its surroundings; as will appear later, all that is necessary besides the electrolyte to cause corrosion, is a few voltaic couples embedded in the mass or else free dissociated hydrogen. Iron as cathode is less liable to corrosion, and this fact is taken advantage of in engineering work, to inhibit rusting.

The electrical inoxidation process of de Meritens (10), is a reproduction on a large and rapid scale of the process of electrolytic corosion. Iron containing occluded, and therefore dissociated, hydrogen, and immersed in warm distilled water, is rusted by connecting it to the positive pole of a battery supplying a current of very low voltage; if the current is as weak as can be made to pass thru the water, the formation is one of black oxide, or the rust is converted into black oxide. If the iron is free from hydrogen it is necessary to first connect it to the negative pole so that it may absorb some. The part played by hydrogen in this process is very interesting

(8) Cushman, Loc. Cit., p. 15.
(9) Italics not in original.
(10) Bull. Soc. Intle. Electr., vol. 3 (1881), No. 29, p. 230.

and bears out the statement of Dr. Cushman which has been quoted. The dissociated hydrogen is not merely a by-product in the process of rusting, it seems to play an essential part in "setting-off" the reaction by creating a galvanic current. Free hydrogen ions are known to be extremely active catalytic agents; we will return to this subject later.

That the operation of rusting is of an electrolytic nature was very beautifully shown in the experiments suggested by Professor W. H. Walker and carried out by him in collaboration with Dr. Cushman (11). A "feroxyl" reagent was prepared by neutralizing a hot solution of gelatine with 1/100 normal potassium hydroxide, using phenolphthalein as indicator, after which a few drops of a dilute solution of potassium ferricyanide were added. The pieces to be tested were immersed in this preparation which solidified on cooling, encasing them; diffusion being retarded by the colloidal nature of the medium, local discolorations were expected to indicate the progress of chemical action. In these experiments the development of hydroxyl (HO) ions at the negative poles was shown by a pink coloration due to organic anions from the phenolphthalein, and at the positive poles the solution of the iron was shown by the blue coloration due to the ferrous cations.

In these tests it was found that, as a rule, the ends of the test-pieces were positive, giving rise to a blue coloration indicating ferrous ions, and rust was formed; at the central part where the pink coloration developt, the iron remained bright. The photographs published by the experimenters show nails which have their positive poles situated at the head and in most cases at the point also; this suggests that the compression of the head by upsetting and the squeezing of the end between the cut-off dies when the point is formed, resulting in an overstrained (crystallized) condition of these parts, may account for their positive polarity. After a while there would take place a complete reversal, the positive and

(11) Cushman: Loc. Cit., p. 3.

negative poles changing places until a further reversal brought back the original conditions, and so on continuously; in this way the different parts of the test-pieces rusted alternately.

The change of polarity is no doubt due to the formation of rust which would in time change the potential of the positive nodes in relation to the negative nodes. That after the first reversal a balanced system is not reached when there is an even coating—as far as the eye can judge—all over the pieces, might be due to an effect of persistence, similar to hysteresis, which would carry the action over the neutral point, as a fly-wheel carries an engine over the dead-center, but is more likely due to the very fact that rusting starting at separate points, there can be no really even coating as far as depth is concerned. Iron never becomes passive thru rusting.

Dr. Cushman gives a fine discussion of the relation of this electrolytic theory to the rusting of iron ([12]). He shows that if a piece of iron or steel is immersed in water, positive and negative spots are established; iron passes into solution at the positive spots and is converted into hydroxide, part of which piles up around those spots in crater-like formations, the rest migrating to the negative spots where it collects in the form of cones. Microscopical examination readily proves this to be the case; it is undoubtedly the correct description of "pitting" which, whether on a small or large scale, always initiates the process of rusting. Rust cannot take place unless negative and positive spots are established, the latter rusting first and continuing to do so until their polarity has changed. Hence, homogeneity is the best insurance against corrosion. A speck of impurity will give rise to a positive annulus if it is negative to the iron surrounding it. In 1822, Stodart and Faraday showed ([13]) that voltaic couples being present thruout the mass of commercial metals are the cause of these impure metals being dissolved more rapidly by acids than those which are of purer composition.

(12) Cushman: Loc. Cit., p. 27.
(13) Phil. Trans. Yr. 1822, p. 253.

THE SOLUTION OF IRON IN WATER

The actual solution of iron by water, whether brought about directly by the voltaic effect of the contact between the metal and its impurities, indirectly by the hydrogen ions set free by that voltaic action and giving rise to further voltaic action with the iron, or by any other causes, is the crucial point of the electrolytic theory of corrosion. Whitney seemed to have proved beyond a doubt that iron is soluble in water ([14]), and yet Dunstan and others failed to obtain any solution whatever under apparently identical conditions; they therefore rejected the theories that hydrogen is evolved during rusting and that iron dissolves in *pure* water. Dr. W. H. Walker supported Whitney's theory of the solution of iron as positive ions; under the same conditions, in distilled water, it is asserted that lead also will go into solution ([15]). To help solve the problem, Dr. Cushman devised a simple method ([16]) for testing iron and steel samples in water free from air and carbonic acid. In every case the metal remained bright, but rusted as soon as air was admitted. To find out if iron did actually go into solution before the admission of the gases, a small amount of phenolphthalein was added; sooner or later it showed the presence of iron by its pink color. The smallest amount of iron which could be detected in this way would be .0004 gram, and it was claimed that the indicator, altho itself a weak acid, could not account for the solution of the iron. If uniform confirmations of these results are forthcoming from equally reliable sources, the electrolytic theory of corrosion is proven, at least for *ordinary* iron, because in all these tests, while taking into account the composition of the medium, the experimenters apparently fail to take into account the minute variations which must have existed between the various so-called pure irons used. It may well be doubted if theoretically pure iron would dissolve in theoretically pure water, in which case the solution of iron, as observed by Cush-

(14) Jl. Am. Chem. Soc., vol. 25 (1903), p. 10.
(15) F. Clowes: Nature, 1908, p. 560.
(16) Cushman: Loc. Cit., p. 17.

man, would be due to the galvanic action between the iron and its impurities, causing electrolysis of the water, the hydrogen liberated then forming a couple with the iron, the latter being the positive and soluble partner. Dunstan and others may have experimented with an iron of greater purity than that used by Cushman.

Dr. Cushman further explains Dunstan's failure to confirm Whitney's results, by arguing that by his method of operation he could not have had more than 0.000001 gram of iron in solution, and this would be too small a quantity to detect by means of the phenolphthalein indicator, and yet, would be sufficient to induce corrosion. He concludes that the rusting of iron is primarily due, not to attack by oxygen, but by *hydrogen* ions, in fact, as will be shown later, oxygen may, under certain conditions, inhibit corrosion.

The cause of iron going into solution remains to be found, but consideration of the influence on corrosion of the many impurities present in iron and steel may, as just stated, lead to the correct solution. The subject will be treated in a separate section, but the author's opinion may here be stated that the process of rusting, under the most favorable condiions, is as follows: Voltaic action between the iron and its impurities, or among the impurities themselves, causes hydrolysis, or electrolytic decomposition of the water. If the impurities are negative to the iron, iron will go into solution; if the impurities are positive, they themselves will dissolve and the iron will remain immune. The *role* of the *free* dissociated hydrogen derived from the water (as against *combined* hydrogen to be considered shortly) is of a catalytic nature. The free hydrogen is negative to the iron and by its contact effect causes its solution. The product of ordinary electrolysis of water by an electric current is two atoms of hydrogen and one of oxygen; the slow reaction of rusting results, apparently, in the formation of an atom of hydrogen and one of hydroxyl; that a difference of this nature should exist is not surprising; as we have already seen, different rates of oxidation produce different oxides. Once the iron is in solution, or

on the point of solution, it will be oxidized by any free oxygen present.

With rise of temperature, the readiness of iron to oxidize increases. Hot iron decomposes steam, yielding an impure hydrogen, and is oxidized; corrosion is brought about by a similar action, but very much slower, voltaic electricity taking the place of heat. The first cause of corrosion, therefore, may be the electrolysis of water, followed by an electrolytic or catalytic action of the nascent hydrogen on the iron.

ACTION OF OCCLUDED GASES

Occluded gases must next claim attention. Graham found that iron cooled in hydrogen absorbed 46 per cent of its volume. John Perry in 1872 ([17]) detected the presence of hydrogen in steel. Ledebur found 0.0017 per cent of hydrogen in a soft open-hearth steel. These observations are of interest because, hydrogen being negative to iron, it will, as already stated, promote its solution and corrosion. The electrolytic activity of hydrogen was pointed out by Roberts-Austen ([18]).

According to Lenz, 45 per cent of the absorbed gases in iron may be hydrogen, the balance being carbonic dioxide, carbonic oxide and nitrogen in about equal proportions. According to F. C. G. Muller ([19]) about 67.8 to 90.3 per cent of the gas in steel is pure hydrogen.

It is a well-known fact that iron or steel containing occluded hydrogen, due to pickling in acids, is hardened to a considerable extent and is readily oxidized while in that condition; thoro washing and neutralizing of the acid will not correct the hardness nor the readiness to oxidize. Gas occlusion by this method may, normally, reach 12 times the volume of the iron, proving that most of it must be alloyed or in a liquid or solid state. The greater proportion of this absorbed gas is hydrogen and it must, necessarily, be as impure as that

(17) Jl. I. & S. Inst. Yr. 1872, p. 240.
(18) Fifth Report, Alloys Research Comm., Inst. Mech. Engrs., 1889.
(19) Deuts. Chem. Gesell., vol. XII (1878), p. 11.

which rises in the pickling vats, containing, therefore, hydrogen sulfide, arsenide, etc.

On the other hand, electrolytically produced iron, which is quite difficult to corrode, is hardened to a considerable extent by the absorption of hydrogen during its deposition. The hardness of electrolytic iron is 5.5 as against 4.5 for ordinary iron. According to Cailletet ([20]), electrolytic iron will hold as much as 250 times its own volume of hydrogen and the alloy containing 0.028 per cent (by weight) of hydrogen will scratch glass. This absorbed hydrogen must be relatively pure, and while this may preclude electrochemical activity among the gases themselves it can hardly have much bearing on the difference of behavior between it and pickled iron, when exposed to corroding agencies.

The hydrogen contained in pickled iron can be almost entirely baked out of it at a low temperature; not so with the hydrogen absorbed electrolytically. This tends to show that in the pickled iron, the gas is not so permanently or stably combined—if combined at all—as in electrolytic iron. Furthermore, the great volume of the gas taken in by the electrolytic iron shows that a very large percentage must exist in solution as an alloy with the iron. The co-existence of three states of matter has been supported by Graham, Wiedermann and Spring. While there may be just as much free dissociated hydrogen contained in the pores of both classes of iron and the tendency to rust from that cause may be the same, yet the larger amount of hydrogen-iron alloy in the electrolytic iron may resist corrosion much better than iron alone. The quality of resistivity to corrosion is intimately connected with the rise in electrical conductivity which is brought about by the chemical union of hydrogen with metals. Hot iron when quenched in water absorbs hydrogen, and Richards and Behr ([21]) have found that the electrode potential was raised by 0.15 volt, the nature of the gas being apparently the same

(20) C. R., vol. LXXX (1875), p. 319.

(21) T. W. Richards & G. E. Behr Jr. Zeits. Phys. Chem., Mar. 5, 1907.

as that which is absorbed in the presence of nascent hydrogen and therefore by electrolysis. The hydrogen taken up by finely powdered iron reduced at a low temperature was not found to affect the e. m. f.; we may infer that the physical conditions attending the production of this iron were insufficiently powerful to cause the alloying on which the change of e. m. f. seems to depend. Dr. Steinmetz finds that electrolytic iron has a very high hysteresis loss, but attributes it to occluded nitrogen.

From an examination of all these facts, it would appear that the increase of potential due to the alloyed hydrogen in electrolytic iron overcomes the effect, as an electro-negative catalyzer or otherwise, of hydrogen in a free ionic state only. In all classes of iron the hydrogen exists in both conditions, free and combined, just as carbon does in pig-iron, but the proportion of hydrogen-iron alloy in electrolytic iron is very much greater than in the other metals. Hydrogen, like carbon, when present in a free state will by contact action promote corrosion; like carbon also, when chemically combined with the iron it will resist corrosion, but if the alloy is unevenly distributed the pure iron in contact with the alloy will be attacked.

According to Roberts-Austen, silicon, manganese and aluminium prevent the escape of hydrogen from iron; Ledebur claims ([22]), however, that brittleness after pickling, due to hydrogen, is greater if the combined carbon is high, while silicon has the reverse effect; he is in accord therefore with Troost and Hautefeuille ([23]), who claim that silicon diminishes absorption. These seemingly opposite statements may be reconciled by assuming that while silicon may reduce the absorption of hydrogen, it will also retard its subsequent removal, just as non-conductors which absorb heat with great difficulty will, on that very account, retain it the easier. Manganese is said ([23]) to greatly increase the absorption of the

(22) Mitt. Kon. Tech. Versuchsanstalten. Ber. Yr. 1890. Suppl. I. 1907.

(23) An. Ch. & Ph., 5e S., vol. VII, p. 1155.

gas while diminishing that of carbonic oxide which is, in any case, very slight. Manganiferous pig-iron retains more gas than does ordinary pig.

Pressure applied during the solidification of metals—as, for instance, in the Whitworth process—prevents the escape of the gases. They can be driven out by heating, preferably *in vacuo*, or locally by machining or drilling; the combination is, therefore, not a very close one. To drive the gases out of pig-iron, a temperature of 800 deg. C. is sufficient. Malleable iron contains more carbonic oxide than hydrogen and it is retained with greater energy. Steel is said to absorb somewhat less than cast-iron, and wrought-iron less than cast-iron; these differences are, in great measure, no doubt, functions of the porosity.

Occluded gases, and especially hydrogen, must not be lost sight of when dealing with the problem of corrosion. Hydrogen is the lightest and, therefore, kinetically the most active of elements; it is in a way, a sort of universal catalyzing "daemon," an extravagant statement to the ear, perhaps, but with some merit of suggestiveness; all chemical reactions take place in the presence of hydrogen, and it is the only element of which this is true. Hydrogen, which seems to form the main ejection from the sun, and may be regarded as closest to the primordial element from which, according to recent well grounded theories, all other elements may proceed, is unique in many of its properties; it seems to stand apart from the other elements in many ways. These differences are, in many cases, attributable to the great activity of its molecules in proportion to their mass, hence, for instance, the distinct character of its curve representing the value of $p v$ under different pressures.

The diffusion thru a finely porous material which gives rise to dissociation, is similar to, if not identical with osmosis; in osmosis the porous membrane causes dissociation resulting in chemical effects which are the basis of important reactions and, among others, of organic growth and life.

Hydrogen will pass thru platinum and red-hot iron (Ste.

Claire-Deville) and its ready dissociation, which was demonstrated in Winklemann's important study of its diffusion thru palladium ([24]) suggests a belief in its breakdown, under conditions of common occurrence, into free and active atoms, ready to take the first opportunity offered of entering into a combination. The condition of most common occurrence is, as we have seen, the contact of dissimilar substances. The occlusion of free hydrogen in coal-dust, wheat-dust, zinc-dust and other dusts, will go far to account for their detonation by spontaneous oxidation. These dusts act in the same way as does spongy platinum on certain gases which it ignites by simple contact. A porous material like iron or steel should have a similar effect, but its action would be slow and progressive instead of sudden; instead of spontaneous oxidation we get slow oxidation, rusting.

We thus have additional reason to believe that free dissociated hydrogen ions, generated by the electrochemical action on moisture of iron in contact with its impurities or other substances exterior to itself, induces by catalytic excitation or an electrical effect of its contact with the iron, the solution of that iron as free ferrous ions which unite with free oxygen to form rust.

THE DIFFERENCE BETWEEN IRON AND STEEL

The principal difference between iron and steel lies in the carbon content. Iron having over 0.04 per cent of carbon is usually called steel; if there is less than about 0.15 per cent, it is known as a mild steel. Save in the arrangement and distribution of the constituents, it cannot be said that, chemically speaking, there is any sharp line of demarcation between iron and steel, but the processes of manufacture are different and the two metals have therefore different physical properties.

Steels, with the exception of the very mild ones, are susceptible to being hardened, and it is well to note that steels harden by changes in the carbides, whereas chilled iron is

(24) An. Phys. Chem. Wied., vol. 6, p. 104, and vol. 8, p. 388.

hard because of a change in the structure of the surface from crystalline to amorphous, or nearly so.

Carbon is present in iron and steel, either as microscopic flat crystals of graphite, or as carbides of iron of which a number of varieties are known, more or less distinct from each other. The most common one is *cementite*, a definite compound, Fe_3C; *pearlite*, an intimate mixture of cementite and ferrite (pure iron) forms the bulk of most steels and *martensite* is the carbide produced by sudden cooling. Sulfur, phosphorus and silicon are present as sulfides, phosphides and silicides. Manganese, which is added as ferro-manganese in the process of manufacture to prevent the occlusion of gases, is always present, either alloyed or in combination with the non metallic impurities. In special steels there may be nickel, chromium, tungsten, molybdenum, vanadium, etc. If the impurities are not dissolved in the iron they will separate as eutectics; this will depend in great measure on the heat treatment and mode of cooling.

THE STRUCTURE OF IRON AND STEEL

The normal structure of iron and steel is crystalline; fibrous iron is a misnomer, the fibrous appearance is due to the way in which the crystals draw out from each other in the direction of their main axes when the metal is fractured. The more slowly and uniformly the heating and cooling have been carried out, and the less interference there has been by mechanical distortion, the more regular and small will the crystals be; these crystals always lie in the direction of the heat waves passing out in cooling; they are, therefore, at right angles to the contour planes of the piece; it is on this account that sharp angles are to be avoided in cast metal work, as they cause a sudden change of direction in the position of the crystals. When cast-iron is "chilled" it appears to be set in a more or less amorphous condition, hence its lack of flexibility.

A change in the crystalline structure of iron may be brought about by shock or continual vibration; the fracture becomes coarser and there is a simultaneous loss of strength;

the iron is said to be *crystallized.* The strains which alter the mechanical condition of matter are: crushing, tensile, flexional and torsional. The factors governing variations in the results will vary according to the moment of the strain, or its average intensity multiplied by the period during which it acts. The effects of strain will also vary in different parts of the same piece from differences in the original heating, lamination, forging or cooling which it may have undergone. Shearing, punching and other operations will alter the structure; the walls of a cold-punched hole are unfit for threading because they are desaggregated, hence they should be drilled or reamed out. Swaging, unless performed gradually and at very high speed, will have a tendency to crush the material and make it "short," whereas light, rapid swaging and drawing thru dies will tend to interlock the crystals. If annealing is required after drawing wire and sheets, it is because the crystals are not as regularly and snugly packed by exterior mechanical means as they are by the crystallogenic forces which act during cooling from high temperatures. It is evident, then, that all manufactured goods must be more or less heterogeneous in their structure.

RELATION OF STRUCTURE TO CORROSION

It is found that, apart from chemical and voltaic causes, corrosion will vary according to the structure of the material and the mechanical treatment to which it has been subjected. It is also known that metals in large masses will not corrode as rapidly in proportion to the surface exposed as will smaller masses of the same composition and in the same physical condition. The reasons governing these facts are still obscure notwithstanding the many plausible theories which can be advanced.

Hard cast-iron is less corrodible than soft cast-iron of similar composition ([25]), and it corrodes faster if cooled irregularly than if cooled uniformly and slowly. The inner portions being more uniform in texture, corrode more uniformly

(25) W. J. McAlpine, Trans. Am. Soc. C. E., vol. 1 (1868), p. 23.

and slowly (Mallet). The more porous the material, the more rapidly will corrosion proceed and the more deep and destructive will it be. Blowholes of any size invite rust. It has been found that iron gun-barrels corrode more rapidly in wet weather than those made of comprest steel (W. A. Adams). As first discovered by Kalischer, metals conduct electricity better when their structure is crystalline; an amorphous metallic foil which has been rendered crystalline by careful heat treatment will become a better conductor. Increased conductivity implies better resistance to corrosion.

The microscopic porosity of iron and steel has been shown and even measured by Thorner ([26]). Under ordinary circumstances, water cannot pass thru the pores and fissures in iron, on account of their capillary action, but a high pressure will overcome this capillarity as shown in the "sweating" of hydraulic presses. The absorption of gases likewise proves the porosity of iron and steel. At high temperatures all metals absorb gases, losing part of them again upon cooling. As already stated, all manufactured iron and steel goods have to undergo some form of heat treatment and are found to contain hydrogen, nitrogen and sometimes carbonic oxide.

Carelessness of manufacture which tends to heterogeneousness, is an invitation to corrosion and in itself goes far to explain why modern steel, which is tortured into shape at such a high speed that the molecules are not permitted to readjust themselves, is said to be more corrodible than the metals produced a generation ago; in those days iron and steel were produced in small quantities, without the addition of other metals, and were rolled slowly and allowed to cool naturally. Tho internal strains due to mechanical treatment are not to be confounded with the unevennesses in the distribution of the impurities due to segregation in cooling; these mechanically induced strains are really equivalent to straining the metal beyond the elastic limit which, as will be seen later, makes it more corrodible. Moreover, the tonnage-craze from which the quality of product in so many industries is to-day suffering,

(26) Stahl u. Eisen, vol. VI.

is causing to be placed on the market a great mass of material, only a small proportion of which is *properly* inspected, which is not in proper condition to do its work—rails and axles which fail in service and steel skeletons for high buildings which may carry in them the germs of destruction and death.

EFFECT OF STRESS ON CORROSION

"The effect of stress on the corrosion of metals" is the title of an instructive paper by Thomas Andrews, published in 1894 ([27]), in which the results of extensive electrolytic tests made in saline solutions are recorded. In all classes of tests, tensile, torsional and flexional, the results were of the same nature; the unstrained parts were, by galvanometer readings, shown to be electro-positive to the strained parts and hence more subject to corrosion. On the other hand, according to experiments made in France that same year, if iron and steel are strained beyond their elastic limit, the surface corrodes with greater rapidity along the lines of deformation, where molecular cohesion has been broken down and the metal been made more porous. The author's own observations of over-strained bolts confirm this view, and it is a well-established fact that the metal around punched holes will rust more rapidly than that around drilled holes, because the degrees of strain differ.

Dr. Charles F. Burgess found ([28]) that in steel strained tensionally and torsionally to just below the point of rupture, the strained parts corroded very much faster than the unstrained; the unstrained ends being cathodes, bubbles of hydrogen were given off from them under water. These results in no way invalidate those of Andrews; Dr. Burgess worked with pieces strained beyond the elastic limit and they had undergone permanent structural deformation, whereas Andrews worked within the safe limits allowed by engineers, where no permanent deformation within a long period of time is to be feared.

(27) Proc. Inst. C. E. Yr. 1894, p. 356.
(28) Trans. Am. El-Chem. Soc., 1908.

In recent experiments made by E. Rasch ([29]), it was found that during tensile tests of brass and mild steel, within the elastic range the metal became cooler and beyond the critical point or elastic limit it became hotter. A loss of heat is to be expected during structural breakdown and its connection with the change of electrical conductivity is evident. Some years ago A. Witkowski found ([30]) that in a strained metal there is an increase of electrical resistance in the direction of the strain.

All these observations go to prove the claim that mechanical treatment, by setting up uneven strains in different parts of finished pieces, will create variations of potential which will promote rusting. Whatever the composition of the different inner parts of the metal may be, and apart from any action which may be due to difference of composition, if there is a difference of molecular aggregation, it will promote the rusting of one or other of those parts. Action, power, everything knowable depends on difference of potential, and any chemical or physical difference between two portions of matter in contact must give rise to a difference of potential and a flow of electricity.

If straining a metal below its elastic limit by exteriorly applied mechanical means will make it electro-negative to the same metal unstrained, the strains set up by chilling or hardening should have a like effect; the metal should resist corrosion to a greater extent and promote the corrosion of more positive metals in contact with it. This is found to be the case. Eighty years ago Daniel observed that a certain steel was dissolved by hydrochloric acid five times as rapidly when unhardened as it did when hardened; this is an indication of what we may expect with the agents of corrosion. Prof. Chas. E. Munroe ([31]) mentioned the case of a cold-chisel, tempered at the end, which had been dropt into an engine-room channelway of the S. S. Triana in 1874; when found, some years later,

(29) Preuss. Akad. Wiss. Ber., vol. 10 (1908), p. 210.

(30) "Effect of strain on electric conductivity": Trans. Roy. Soc. Edin., vol. XXX (1881), p. 413.

(31) Jl. Franklin Inst. Yr. 1883, p. 302.

the hardened part was not corroded, but the soft part was, and especially so at the line of immersion in tempering which was clearly defined; at this point the contact-action was, of course, most pronounced; had the chisel been hardened thruout, it would, no doubt, have rusted all over; as it is, however, the soft part protected the tempered end, just as zinc will protect iron under similar circumstances.

"What becomes of the energy of a coiled watch spring when it is dissolved in acid?" is supposed to be one of the many unsolved mysteries of Science. The energy of the coiled watch spring is indicated by a slight shift of its potential towards the negative end of the electro-chemical scale, resulting in an increase of e. m. f.; when the spring is put in acid, the energy is expended in retarding the action of the acid and is equivalent to a drop of temperature which would restrain chemical action. The energy of the spring, as increased e. m. f., counteracts the energy of the acid; it is expended and disappears as work of a negative character.

COMPARATIVE CORROSION OF IRON AND STEEL

From a theoretical standpoint, steel, being negative to iron, should be the least corrodible of the two. As a general thing, results of tests between iron and steel have, in the past, resulted in favor of the iron; in most cases, the experimenters were undoubtedly looking for the defeat of the new material, steel, and their state of mind helped them to find it. There are, however, a large and ever increasing number of contrary observations recorded, especially where the tests have been carried out on a large commercial scale and with qualities of recent manufacture. The opinion one is led to form from a careful examination of recorded observations is in agreement with that of Ewing Matheson ([32]), namely, that properly protected steel and iron rust to about the same extent, the steel doing so more uniformly; this is, of course, subject to the variations of structure already referred to, and those of chemi-

(32) Proc. Inst. C. E., vol. 69 (1882), p. 1.

cal composition, especially as regards metallic impurities, which will be considered later.

A most important paper was presented before the Institute of Civil Engineers in 1881 by David Phillips ([33]), "On the comparative endurance of iron and mild steel when exposed to corrosive influences"; excellent tables are given and the general conclusions favor iron. A distinction must here be made between the cast and wrought metal: cast iron will not rust as readily as wrought iron unless the skin is removed, in which case it will rust faster.

It must be borne in mind, as a limitation to all results adduced, that while the initial rusting may be greater with either material, iron or steel, the rates of progression may be different and may bring about a complete reversal in the final result; the material which rusted faster at first may outlive the other. This is especially apt to be the case with forged, rolled and drawn metals. Future tests should, therefore, either be carried out to destruction, as advocated by Howe, or else to the point at which failure of the material in service would result from loss of useful area.

The most radical difference between iron and steel is the slag which is always present in the iron; while this slag may protect the metal immediately beneath it, its contact effect on the exposed iron surrounding it must more than counterbalance this slight advantage. But while this may be the most radical difference between the two metals, the most important one for the present discussion is the difference between the amount and composition of the carbides of iron.

The carbides of iron have a greater specific heat than iron itself: this implies a high resistance to corrosion; the difference varies directly as the carbon content and is, according to Meuthen ([34]) 0.0011 for each 0.5 per cent of carbon. According to these investigations, the specific heat of cementite is 0.1581, whereas that of ferrite is 0.1432; these values check up closely by Kopp's law of molecular heat. A galvanic current

(33) Proc. Inst. C. E., vol. 65 (1881), p. 73.
(34) Metallurgie, vol. 5 (1908), p. 173.

must be created by contact of the carbides and the ferrite. A steel containing about 1 per cent of carbon is practically a compound of carbon and iron; it is a most intimate mixture of ferrite and cementite, known as pearlite; on this account it does not pit readily; if by quenching from a high heat it is converted into austenite or martensite, this tendency is further inhibited. The author has found that in the case of two identically similar disks of steel, cut one after the other from the same bar, and exposed together for about two years to ordinary agencies, the unhardened disk had 69.1 per cent of its surface corroded, whereas the hardened disk had only corroded over 56.8 per cent of its surface; the difference is not great (20 per cent), but it should be mentioned further, that the rust on the hardened disk was of a darker shade than that on the unhardened disk.

Iron contains very little carbon; it is therefore a loose mixture of ferrite and carbides; there are spots of carbide scattered about because there is not enough carbon to permeate the mass thruout and form an alloy as in the case of steel; each particle of carbide is a center for the promotion of rust.

INFLUENCE OF MODERN CONDITIONS

The prejudice existing against steel may be due to the changes in the conditions surrounding the use of iron and steel, especially the composition of the waste gases of combustion which pollute the atmosphere and the employment of electricity for lighting and transportation. To quote Prof. H. M. Howe (35): "The fact that steel has come into wide use simultaneously with a great increase in the sulfurous acid in our city air and of strong electric currents in our city ground may well lead the practical man, be he hasty or cautious, into inferring that the rapid corrosion of to-day is certainly due to the new material of to-day, steel, whereas, in fact, it may be wholly due to the new conditions of to-day, sulfurous acid and electrolysis."

This prejudice may also be due to the fact that, whereas

(35) "Corrosion of iron and steel": Am. Soc. Testg. Mats., 1906.

the iron of some years ago was more homogeneous and freer from slag than the iron of the present day, the steel which is now manufactured is perhaps more homogeneous than that which was made during the early years of the industry, when only small masses were handled. In puddling, working on a small scale will give a better iron, freer from impurities, but in steel making, working on large masses of metal will, within certain limits, assist the diffusion of the components by maintaining the metal thruout at a more even and higher temperature for a longer period of time.

CORROSION IN AIR

Iron will not corrode in air unless moisture is present, and it will not corrode in water unless air is present. This rule applies to salt-water also; R. Adie found (36) that corrosion did not take place in salt-water if air or oxygen was excluded, and that alcohol containing oxygen but no water would not cause corrosion, all of which accords with the generally accepted theories.

Iron having a specific gravity of 7.8, produced in the laboratory, as against 7.3 for commercial pig-iron, is slightly oxidizable in moist air, but iron of a specific gravity of 8.14 produced in the electric furnace, is scarcely at all (37). This merely bears out previous statements.

The agents present in the air which accelerate rusting, especially in or near cities where much fuel is consumed, are numerous, but sulfur dioxide and soot are probably the most destructive because together, in the presence of moisture, they conspire to produce sulfuric acid. The action of these two agents is most marked in railway tunnels and bridges. Wm. Kent has studied the action of sulfur dioxide (38): an analysis of sooty rust from a railway bridge showed the presence of sulfur dioxide, sulfuric acid, carbonic acid, chlorine and ammonia. Valuable papers on the decay of materials in tropical

(36) Proc. Inst. C. E., vol. IV (1845), p. 323.
(37) Genie Civil, vol. 9 (1886), p. 247.
(38) Jl. Franklin Inst., Yr. 1875, p. 437.

climates were presented before the Institute of Civil Engineers in 1864 ([39]).

CORROSION IN FRESH WATER

The impurities in fresh water vary with the locality. Rivers flowing thru industrial towns will contain hydrochloric and sulfuric acids and acids due to the decomposition of organic matter; all are highly corrosive.

Carbonic dioxide, air and excess of oxygen, all of which will accelerate corrosion, are present in all waters to a varying extent. Silica and alumina are without direct chemical effect. The variable impurities are as follows: carbonates of lime, iron and magnesium; sulfates of lime, potassium and magnesium; nitrates of lime and potassium; lastly, the chlorides of sodium, potassium and magnesium which accelerate corrosion to a considerable extent. Salts which, like sulfates and chlorides, hydrolyze in solution to an acid reaction, promote rusting to a greater extent than when they remain neutral.

Water near the surface is more corrosive than lower down, because of the larger percentage of dissolved carbonic dioxide and air. Alternations of wetting and airing will increase the rate of corrosion, and on this account the most vulnerable part of a ship's hull from the outside is that part known as the wash-space; continuous immersion is less destructive.

All and any impurities in water will accelerate corrosion; if the rule of uneven composition promoting the corrosion of iron is true, it must apply to the medium also. A heterogeneous medium must, necessarily, be the seat of voltaic currents, the effects of which would be to supply the hydrogen ions required to induce corrosion. On this theory, any soluble—and possibly, even, insoluble—substance would promote rusting in water, even if it were without direct chemical effect on the iron; if any other substance is present which will attack the iron, the action will be hastened, as in the case of carbonic acid which has already been discust.

In the case of ironwork at the mouth of a river, where the

(39) Proc. Inst. C. E., vol. XXIV (1864), pp. 1 to 37.

water is brackish, strata of different degrees of salinity are to be found; on this account the rate of corrosion is particularly rapid at the point where the water is most salty; it is, on a large scale, the effect suggested as taking place in each drop of every non-homogeneous medium.

Rain water is relatively pure, but even it will contain salts dissolved from the dust in the air, which increase its conductivity and rusting properties. Theoretically pure water would be a non-conductor and could not, therefore, serve as the electrolyte in the process of rusting.

CORROSION IN SALT-WATER

In sea-water the proportion of chlorides is very much greater than in fresh water; moreover, some ammonia and the bromides of magnesium and iodine, all of them powerful aids to corrosion, have to be reckoned with. Sewage, which is almost always present near the mouth of rivers, supplies sulfates, nitrates and organic matter. According to records, the most salty seas are the Mediterranean and Dead seas, and the least salty are the Baltic and the Black seas.

Saline matter in water decomposes in contact with iron which fixes the negative elements; it also serves to increase the conductivity of the water considered as an electrolyte and, as already suggested, increases the heterogeneousness of the medium, resulting in galvanic action in the medium itself which may supply hydrogen ions. The most extensive and complete investigation of the action of sea-water on the metals of ships is due to Robert Mallet [40], and he has published some very important tables.

When cast-iron is left in sea-water for a long period of time, it undergoes a remarkable change, being converted into a pseudomorphous mass of a black substance resembling plumbago. As far back as 1822 it was known that slightly acidulated water would have this effect on iron, and 40 years later Dr. Calvert found this to be the case with salt water also. Guns from the wrecks of the Royal George and the Royal

(40) Trans. Inst. Nav. Arch., vol. XIII (1872), p. 90.

Edgar, which had been under water 62 and 133 years, respectively, were found to have become black and soft, so that they could be cut with a knife, and when brought up into the air they absorbed oxygen so rapidly that they heated up. They must have been extremely porous. Cast-iron pipe used for conveying salt-water has been known to undergo the same transformation ([41]). A piece of an iron ship's heel-post, which had suffered considerable decomposition of this nature, was found by David Mushet ([42]) to be of the following composition:

Carbon dioxide and moisture	20.0	per cent.
Protoxide of iron (FeO)	35.7	"
Silt or earthy matter	7.2	"
Carbon	41.1	"

Mallet attributes the conversion of the iron into a plumbago-like mass to the action of the carbonic dioxide present in the water. It may be noticed that the very slow oxidation yields the oxide lowest in oxygen; it has been stated elsewhere, on other grounds, that the faster oxidation takes place, the higher the oxide will be.

CONTACT-ACTION IN SEA-WATER

Some tests were made in 1882 by J. Farquharson ([43]) on six plates of iron and six of steel; these were immersed for six months in Portsmouth Harbor, six of each separately, the other six as connected couples; in this way the comparative corrosion of the iron and steel was obtained and also the increase of corrosion due to galvanic action between steel and iron. The following table gives the losses observed in ounces and grains:

(a)	Steel	in contact	0–427
	Iron		7–417
(b)	Steel	separate	3–340
	Iron		3–327

(41) Trans. Am. Soc. Mech. Engrs., vol. XVI, p. 416.
(42) Proc. Inst. C. E. Yr. 1840, p. 3.
(43) Trans. Inst. Nav. Arch., vol. 3 (1882), p. 143.

(c)	Steel } Iron }	in contact	{ 0-297 { 7-770
(d)	Steel } Iron }	separate	{ 4-000 { 3-190
(e)	Steel } Iron }	in contact	{ 2-337 { 6-000
(f)	Steel } Iron }	separate	{ 4-157 { 4-570

These results, which were confirmed by Mr. W. Denny from his experience in the case of the S. S. Ravenna, are interesting to analyze. They show that in two cases only did the steel corrode to a greater extent than the iron, but the difference is so slight that for all practical purposes it can be said that the steel and iron of the experiments (ship-plates) were equally affected. They also confirm the theory that the combination of steel and iron, which is quite frequent in practice, is detrimental to the iron, but protects the steel which is the negative partner. They also throw light on previous observations and lead to the conclusion that good homogeneous iron and steel are about equally corrodible. As we shall see later, the advantage which steel possesses over iron is due to the fact of its not pitting so deeply.

Iron in contact with non-metals will also suffer from galvanic action, as shown in the case of a bolt which was corroded almost entirely thru at the junction of pieces of elm and pitch-pine, which it held together ([44]), and the case mentioned by Matheson of a piece of iron on a bridge which was corroded to a knife edge where it came in contact with wood.

The effects of electroyltic action are clearly demonstrated by the results secured by Mallet in a series of experiments which he undertook in order to ascertain the "amount of corrosion in equal times in clear sea-water of a unit surface of wrought iron plate exposed in electro-chemical contact with an equal surface of the following metals electro-negative to it, as compared with the corrosion of the same surface of the same iron exposed *alone* for the same length of time:"

(44) Proc. Inst. C. E., vol. XII (1852), p. 229.

		Relative Corrosion.
Iron plate alone		8.63 per cent.
In contact with:	Brass (Cu_2+Zn)	29.64 "
	Copper	42.79 "
	Lead	47.90 "
	Gun-metal (Bronze)	56.39 "
	Tin	74.71 "

In connection with the above table, the valuable fact is mentioned that the brass alloys of composition Cu_8+Zn_{17} to Cu_8+Zn_{18} are without galvanic action on iron in sea-water. This explains the incorrodibility of the alloy of iron, copper, zinc (and sometimes tin), which is known as Delta Metal, and which, tested in conjunction with wrought iron and steel, showed remarkable resistance under test, as follows (45):

	Wrought Iron	Steel	Delta Metal
Loss	45.9	45.45	1.2 per cent.

The first copper-zinc alloy for the special purpose of resisting the action of sea-water was patented in 1832 by G. F. Muntz. Muntz Metal is used for bolts, valves, etc., and for sheathing ships; its composition is 2 parts zinc to 3 parts copper. Tobin bronze is similar to Delta Metal, but contains tin and lead.

THE CORROSION OF SHIPS

The interior of ships is subject to various agents of corrosion. At certain points the temperature is higher than at others, and escaping steam keeps the atmosphere moist; the bilge-water, also, is of a highly corrosive character; the coal abrades the sides of the vessel, holds moisture in contact with them and induces the formation of sulfuric acid if sulfur dioxide is present, besides, coal is, in the presence of sea-water, strongly electro-negative to iron. Some cargoes and the fermented or decaying remnants of old cargoes are likewise aids to corrosion. Cement has been used for coating the ship-plates on the inside, but this prevents examination of the hull, and it

(45) Gesundheits-Ingenieur, Yr. 1888, p. 235.

is porous to moisture and gases. Steel lining-plates are perhaps preferable.

CORROSION OF RAILS

The case of steel rails is an interesting one, showing, as it does, the effect of vibration on rusting. A rail which has been in service but has been laid to one side, will rust all over, but especially at the ends where the vibration of the fish-plates has removed the mill-scale, and on the smooth top of the head. On the other hand, a quite remarkable fact, which has been universally confirmed and can be easily observed by anyone, is that a rail while *in service* will not rust nearly as rapidly as one which is lying out of service. The rusting takes place in proportion to the service, and lines over which fast trains pass frequently, causing much vibration, will practically not rust at all, whereas the rails of turnouts or sidings, which undergo less service, and that of a slow nature, will rust to a certain extent. One observer (J. M. Heppel) has reported the case of some rails at Madras, India, which lost 3 lbs. to the yard lying in the yard exposed to the sea air, while the rails in service nearby were not perceptibly affected.

The top of a rail is comprest and smoothed down in service by the grinding of wheel tires, for there is always a certain amount of slip, especially during acceleration and retardation. Galvanic action between the smooth head of the rail and the rest of it has been suggested to explain this immunity from rust, but it is not at all likely that the foot would owe its protection to the thin stratum of denser metal so far removed from it. If that dense skin on the top of the rail were not crushed beyond its elastic limit, it would, on the contrary, tend to accelerate the corrosion of the steel in contact with it.

The real reason for this difference of behavior seems to lie in the observed fact that oxidation is apparently arrested, or at least greatly retarded, by vibration [46]. Explanations seem to stop at this point, but a simple theory can be built on the

(46) Edwin Clark: Proc. Soc. C. E., Yr. 1868, p. 554.

assumption that the vibration causes a shedding of the rust as soon as it is formed on the spots that are not protected by mill-scale, and there is, therefore, no acceleration of the action due to the accumulation of spongy and electro-negative rust. The average speed of corrosion of a vibrating body would be that of the formation of a first film of rust. Most of the actual rust on rails is probably due to the rapid evaporation of rain on the surface. In the case of rails in service, the first film of rust would be confined to bare spots and cracks in the mill-scale and the vibration would prevent its working its way under the mill-scale as would happen if the rail were at rest.

The top of the rail being denser might be expected to resist corrosion better when the rail is out of use; such is not the case, however. The surface has not only been subjected to hammering and crushing, but also to abrasion and rolling, and it has become short and crackelled and sometimes exfoliated; once laid aside, the smooth top of an old rail rusts very rapidly.

THE CORROSION OF TUBES

The carefully acquired experience of the National Tube Co., of Pittsburgh, teaches that the use of steel in place of iron —at least in the United States—for the special purpose of tubing, is to be preferred; the tendency of the steel to pit is somewhat less than that of iron and it welds at the joint fully as well.

The joint investigations of H. M. Howe and Bradley Stoughton confirm these results. It must be borne in mind that the conclusions apply to skelp material only. They are further corroborated by experiments recently made by T. N. Thomson (47), who finds that iron and mild steel pipes corrode about equally, the steel having, however, the advantage in the all-important matter of pitting. In a test of three pieces of wrought iron and three pieces of mild steel pipe conveying hot water during about one year under conditions identically the same, the iron pipe lost by rusting 20¾ oz. in 9 13/32 lbs.

(47) Domestic Engineering, vol. XLII (1908), p. 67.

(13.4 per cent), and the steel pipe 24⅞ oz. in 9 11/32 lbs. (15.6 per cent). The experimenter did not stop short at these figures and argue therefrom, as all his predecessors had done, that the steel pipe was inferior to the iron pipe as a merchant article, altho evidently slightly more corrodible; he estimated the degree of pitting by averaging the measured depth of the five deepest pits in each piece and thence he calculated the number of days the pipe would remain sound and not show a leak; there is no evidence of his having taken into consideration the fact that the internal pressure would cause a leak before the metal was pitted thru; however, the proportions, as shown in the following table, would hold good:

	Steel		Iron
	850.4 days		780.5 days
	780.5		759.7
	759.7		686.5
Average	796.9		742.2

The steel pipe was therefore 54.7 days, or 7½ per cent, more durable than the iron pipe. Hot-galvanized pipe was found to last about 20 per cent longer than the ungalvanized; this result applying to a few pieces of similar origin and tested under conditions where galvanized pipe is generally considered unsuitable, is of little value. If it were correct, galvanizing would not justify its cost.

Mr. Thomson also draws the following conclusions from a large number of observations collected from all parts of the United States: That in the case of pipe buried in the ground and conveying steam or hot water, the exterior corrodes rapidly, but when the pipe is not buried, and unless air and other gases be removed from the water, the interior is corroded more rapidly than the exterior.

The tests of Howe and Stoughton, and the evidence which they have collected, is of great interest. Of ten different tests made by different observers in different places, seven resulted decisively in favor of steel; in the other three cases the results were very slightly in favor of the iron, but in only one of the latter was the material of modern manufacture. The tests

which resulted in favor of steel were as follows, all except the two first being carried to destruction: Seven months in hot, aerated salt-water; sixteen months buried in dampened ashes; exposed to sulfuric acid coal-mine water; in railroad interlocking and signal service; in locomotive boiler service. It was also found that steel tubes made in 1906 pitted much less than those of 1897 from the same makers, indicating the superiority of modern steel over that of some years back in this particular respect. Badly made steel will evidently corrode faster than a uniform product, and the question of the comparative corrosion of iron and steel should not be judged from the behavior of a poor quality; unfortunately, persons afflicted with mental hustling always generalize exceptions.

The Riverside Iron Works found that iron boiler sheets corroded faster than steel sheets when buried in soil which was kept moist with a solution of carbonate of soda, nitrate of soda, chloride of ammonium and chloride of magnesium, which are the most active corroding substances commonly found in water; the results were as follows:

After 23 days	Iron loss.................	0.84 per cent.
	Steel "	0.72 "
28 days later	Iron loss.................	2.06 "
	Steel "	1.79 "

Boiler tubes in service will suffer severely if exposed to the action of fatty oils which, even if perfectly neutral, have a strongly corrosive action on iron in the presence of steam (48). Cottonseed oil, which is used as an adulterant of cylinder oils, must be avoided.

CORROSION OF WIRE

In the case of wire, the consensus of experience seems to be just the reverse from what it is with pipe. In his report on "The Corrosion of Fence Wire" (49), Dr. Cushman quotes the opinion of a concern which is a very large consumer of wire,

(48) A. Mercier: An. des Mines, Yr. 1879, p. 234.
(49) Farmers Bull. No. 239 (1905), U. S. Dept. Agric.

that "Bessemer or mild steel wire will rust or deteriorate much more rapidly than iron wire. In all probability, three times as rapidly." He also found that according to the unanimous opinion of farmers, modern steel wire fencing is much more corrodible than the old iron wire. It is difficult to see why there should be this reversal of properties for wire as compared with tubing, in view of the fact that steel wire has a harder skin than iron wire because, being less malleable, and being harder to draw thru the dies, the packing of the material at the surface is more marked. This is easily proved by treating pieces of steel and iron wire with an acid; the acid eats out the metal on the ends according to its degree of porosity, and it is found that the steel wire shows a denser and better defined skin than the iron. In the case of iron, the honeycombing extends much closer to the edge. The skin seems to resist the action of the acid in the ratio of its density. The same effect of acids may be observed with all rolled material, notably sheets. The greater corrodibility of steel wire must then be due to peculiarities of chemical composition or other causes. In its investigations, the Division of Tests of the Department of Agriculture found, as would naturally be the case, that modern steel wire was, on an average, much higher in manganese than the old iron wire.

INFLUENCE OF THE IMPURITIES IN THE METAL

All non-homogeneous metals and therefore all commercial irons and steels, are doomed to decay unless adequately protected. Of the impurities in steel, the non-metals, with the exception of sulfur, seem to protect. In the case of metallic impurities, those which, like manganese, are themselves more liable to corrosion than the iron, will act unfavorably; others, like nickel and chromium, which are not so sensitive, will protect the iron with which they are alloyed, notwithstanding the fact that by mechanical contact they hasten the rusting; if unalloyed they act adversely, creating centers for pitting. Eutectic areas create centers for corrosion.

The nature and the amount of the impurities in steel have

a marked influence on its corrodibility. Carbon, insomuch as it will allow hardening, will act as a protection, provided it is combined with the iron and uniformly distributed; high carbon steel is less corrodible than mild steel or iron.

Precipitated iron rusts more slowly if mixed with clean charcoal dust than when by itself, altho there is no favorable current set up; a test made by the author showed 16 per cent oxidation as against 18.4 per cent for the iron by itself; part or all of this protection is due, no doubt, to the absorbing power of charcoal for gases and to purely mechanical protection, but if powdered manganese be mixed with the iron, corrosion of the latter proceeds if anything more rapidly, altho it affords the same mechanical protection as does carbon, and is itself more oxidizable. The gray cast-iron, in which combined carbon is deficient, rusts more rapidly than other grades. Spiegeleisen ([50]) resists corrosion better than cast-iron because it is dense and high in carbon. Prof. Howe calls attention to the mechanical protection afforded by carbon *as rusting proceeds*, in the following words ([51]): "As steel is gradually corroded away, more and more of its surface should come to be composed of cementite, and this fact should tend to retard the corrosion of steel, because cementite should protect the underlying free iron or ferrite." And elsewhere: "The cementite is in such extremely minute microscopic plates that the eating away of a very small quantity of the iron from above them ought to bring very nearly the full proportion of this cementite to the surface." It may be stated further that the definite compound, cementite, is much harder than iron—6.5 as against 4.5—and that it is soluable only in boiling hot acids. The resistivity to acids is always an indication of the degree of resistance to corrosion.*

(50) R. Ackermann: Dingl. Polyt. Jl., vol. 246, p. 377; also W. Parker: Jl. I. & S. Inst., vol. 1 (1881), p. 39.

(51) Am. Soc. Testg. Mats., 1906; Iron Age, Yr. 1906, p. 2047.

*This statement, broad as it stands, is incorrect. Reference to the Discussion will show that the relation of acid corrosion to ordinary rusting is very debatable. Further investigation leads the author to the belief that a relation does exist, but only when acids, highly diluted with ordinary aerated water, are used. This agrees with Mr. Unger's statement in the Discussion.

Dr. Dudley found (52) that the presence of coal-gas in the ground materially retarded the corrosion of wrought iron pipe buried in it. In one test at Nashville, the presence of the gas reduced the rate of corrosion by one-half.

Graphite in iron, which is equivalent to uneven distribution of carbon, may promote rusting, but graphite applied to the outside is considered as second to red-lead only as a protection for iron work (Archbutt); this protection is, no doubt, purely mechanical, altho Mr. E. G. Acheson claims that steel, if immersed in water containing defloculated graphite, does not rust as when the graphite is not added.

Phosphorus and silicon both appear to retard corrosion, and this effect may, as in the case of carbon, have some connection with their hardening qualities, or cold-shortening power. If, however, they are present in patches, like the oft-occurring phosphide eutectics, the softer parts, thru contact action with the parts rich in phosphorus and silicon, will be destroyed all the more rapidly. Some authors have claimed that these two elements increase corrosion, but there is no evidence to support the contention apart from the case of uneven distribution which will make any of the impurities rust promoters to a greater or lesser extent. The fact that common iron does not rust as rapidly as the better grades has been attributed by some to the greater percentage of phosphorus in the former.

Dr. W. L. Dudley discovered, some years ago, that segregated manganese formed centers of corrosion, and it is a generally accepted fact that steels high in manganese are peculiarly liable to oxidation; if the proportion is small and uniformly distributed the effect is inconsiderable. The effect of manganese is corroborated by many reliable authorities (53). The mixing of finely divided iron and manganese and subsequent exposure to oxidizing agents, will result in increased oxidation of the iron, the manganese itself being oxidized more rapidly than the iron; if placed in water the electrolytic action

(52) Progressive Age, vol. 26, p. 137.

(53) Abel: Proc. Inst. C. E., Yr. 1881 (Disc. Phillip's paper); Reynolds: Proc. Inst. C. E., Yr. 1881 (Disc. Hadfield's paper).

is evidenced by an appreciable and continuous disengagement of hydrogen. If the metals are alloyed the alloy is more electro-positive than the iron by itself and therefore more readily corroded. Up to a certain percentage, manganese *dissolved* in iron will increase the electrical resistance of the metal, and the loss of conductivity may reach 50 per cent (Cushman). This fact is, no doubt, intimately connected with its corrodibility, the broad rule being that the better conductor a metal is the less it is liable to corrosion; the conductivity of a metal is always reduced by the addition of a less conducting metal. It is known that manganese salts fix oxygen on certain compounds, and that even the solid salts at suitable temperatures hasten the oxidation of many substances; the metal itself will precipitate iron from its solutions and it is reasonable to infer that with iron going into solution in the presence of oxygen, if there is any manganese present, it will aid its precipitation as an oxide. As silicon has the property of hardening manganese, a small percentage doing so to a considerable extent, the influence of manganese in promoting corrosion may be modified by that element.

According to R. Dubois ([54]), some ferro-manganese originally carrying 79.99 per cent of manganese was partially disintegrated by exposure to the weather. The powdery part held 82.17 per cent of manganese and the mass had shrunk to one-half of its original bulk; this goes to prove the instability of the combination between the two metals.

The combination of manganese and sulfur shows a larger difference of potential to iron than manganese alone. The sulfur in steel will unite more readily with the manganese than with the iron, giving a gray sulfide. Some valuable investigations of the effect of manganese sulfide on the quality of rails have quite recently been carried out by Dr. Henry Fay and J. E. Howard ([55]). These investigators show that manganese sulfide separated in the form of fibers is a source of danger in

(54) Bull. Assoc. Belge Chim., vol. 15 (7), p. 281.

(55) Am. Soc. Testg. Mats., 1908; also Eng. News, vol. 60 (1908), p. 94.

steel rails, so that, apart from reasons relating to corrodibility, the combination of high manganese and high sulfur is to be avoided as a measure of safety.

The protection afforded by paints containing manganese dioxide (MnO_2), even after their removal, seems to be due, not to the power which the salt possesses of decomposing hydrogen peroxide, but to the creation of a passive condition due to the formation of a film of black oxide (Woods); by using a very active oxidizing agent in a paint, it is claimed that a slight inoxidation may be brought about and rusting inhibited; some tests of this theory made within recent years have not borne it out. If a Venetian-red (Fe_2O_3) paint is used, there cannot be any protection, even in theory—and almost anything can be done in theory—all metals are electropositive to their own oxides, and on this account paints containing oxides of the metals to be painted are undesirable from a galvanic standpoint. An ideal method for protecting steel against corrosion would consist in giving it a perfectly homogeneous surface before painting, either by removing slag, manganese, sulfur and other impurities chemically, or by depositing electrolytic iron upon it, using a depolarizer to take care of the free hydrogen.

COMPARATIVE CORROSION OF ACID AND BASIC STEEL

Alexander G. Fraser, in a paper read before the West of Scotland Iron and Steel Institute in 1907, gave the results of an extensive investigation of the relative corrodibility of acid and basic steels.

Excepting in the sulfuric acid test, the acid steel was a trifle less attacked than the basic; this may have been due to the manganese being higher in the basic steel, altho the phosphorus was lower. In the case of the sulfuric acid test, the basic steel resisted far better than did the acid steel; the skin of the basic steel plates was scarcely attacked, whereas most of the acid plates were badly corroded. Mr. Fraser suggested that this might have been due to the carbon being in a different condition in the two steels and a sort of case-hardening

of the basic plates having taken place during rolling. From the figures given in the table it would appear that the popular notion about the excessive corrodibility of basic steel is unfounded.

INFLUENCE OF THE ELECTRIC CURRENT

Interesting tests of the effect of an electric current on the speed of corrosion of a steel plate were made by Mr. Gardner, of the Scientific Section of the American Paint Manufacturers Association [56]; the results of the normal tests without current under different conditions are worth comparing with those of earlier experimenters, but the increase in the rate, due to the passage of a current of 1½ volt, is specially worthy of attention. The following is a summary of the results obtained by Mr. Gardner:

1	Distilled water boiled	0.0482
1-A	Same with electric current	0.0870
2	Distilled water and oxygen	0.0601
2-A	Same with electric current	0.1211
3	Distilled water and ozone	0.0768
3-A	Same with electric current	0.1155
4	Pure air oxygen and nitrogen	0.0492
4-A	Same with electric current	0.0911
5	Pure air, with ammonia: Oxygen, nitrogen and ammonia (Little oxide precipitated. Color dark.)	0.0406
5-A	Same with electric current (Little oxide precipitated. Color dark.)	0.0758
6	Pure air, with ammonia: Oxygen, nitrogen and carbonic acid (Color of oxide brighter than any of foregoing.)	0.1030
6-A	Same with electric current (Color of oxide brighter than any of foregoing.)	0.1941
7	Pure air with ammonia and carbonic acid (Color of oxide brighter than any of foregoing.)	0.0921
7-A	Same with electric current (Color of oxide brighter than any of foregoing.)	0.1876

In each case the action seems to have been about doubled in its intensity by the passage of the current.

(56) Jl. Franklin Inst., Yr. 1908, p. 459.

IRON AND STEEL EMBEDDED IN CONCRETE

Reinforced concrete is undoubtedly the building material of the future, because of the wide distribution of cement material and also because this combination of concrete and steel has proved itself within the last few years the best for every purpose and from all points of view except, possibly, that of beauty of form. The one and only serious objection which has been raised against it is the permanence of the reinforcement; it is a question of paramount interest.

In reinforced concrete construction, the steel reinforcement gives the material the requisite quality for undergoing flexional strains under which concrete by itself would fail, as would natural stone, notwithstanding its high resistance to crushing. To take advantage of its qualities, the reinforcement must be placed below the concrete, altho additional reinforcement may be required on the upper part to take care of negative bending moments. The mortar which is applied to the other side of the reinforcement—the lower side in the case of floors and beams—must be sufficient to protect it against fire and corrosion. The lighter coating is usually 1½ inch or more in thickness, depending on its composition, and therefore its ability to resist the disintegrating effect of fire applied for a long time; its composition should be such as to afford full protection against corrosion. It is remarkable but true that but little attention is paid to the latter consideration, altho it is fully as important as the protection against fire.

The majority of tests which have been undertaken to secure data on the corrodibility of steel in concrete, have resulted in the broad conclusion that when properly mixt and applied, Portland cement concrete is an ideal protection against rusting. There is a well-known case of iron hoops embedded in cement for 26 years, which were found unimpaired and with the blue mill-scale intact ([57]). Whether or not, as claimed by Breuille, cement removes any rust which may have existed on

(57) Proc. Inst. C. E., Yr. 1839, p. 37.

the metal when it was embedded, is of secondary importance compared to the action it may have on the unimpaired metal.

Neat Portland cement is known to be an excellent protection against rusting; it has been successfully used as paint for the protection of large structures, notwithstanding its lack of flexibility. On account of this quality it is well to endeavor, wherever possible, to fill in and around the reinforcement and in immediate contact with its surface, with a concrete high in cement and holding a smaller percentage of small gravel or broken stone than what is to be laid above it; it should also be applied very wet to insure good contact and the formation of a film of neat cement on the surface of the reinforcement; for the protective coating a rich mortar, as wet as can be used, is advisable.

Professor S. B. Newberry has explained as follows the protective action of Portland cement: "Portland cement contains about 63 per cent lime. By the action of water it is converted into a crystalline mass of hydrated calcium silicate and calcium hydrate. In hardening it rapidly absorbs carbonic acid and becomes coated on the surface with a film of carbonate, cement mortar thus acting as an efficient protector of iron, and captures and imprisons every carbonic-acid molecule that threatens to attack the metal. The action is, therefore, not due to the exclusion of the air, and even tho the concrete be porous, and not in contact with the metal at all points, it will still filter and neutralize the acid and prevent its corrosive effect." This explanation will no doubt satisfy the followers of the carbonic-acid theory of corrosion, but the fact will remain that at points where there is no contact between the cement and the metal, corrosion does quite often take place; however, the protection against carbonic acid afforded by the cement must be an efficient retarder of corrosion. An insoluble carbonate is an excellent impermeable screen against corrosive influences, and its value is well illustrated by the remarkable passivity of sheet-zinc roofing which has been weathering for scores of years on thousands of buildings in European cities.

With many styles of reinforcement, it is difficult to employ a selected strength of mix in immediate contact with the steel; with reinforcements made from sheet metal it can, however, be readily done. Professor Chas. L. Norton has made tests which show that, while neat cement affords perfect protection to steel, concrete does not; it is thus of the very greatest importance that the cement be sufficiently wet to insure a film of neat cement forming on the surface of the reinforcement, and that the concrete be everywhere well rammed.

As far as subsequent rusting is concerned, it would seem to be of little importance whether the reinforcement be clean and free from rust or not at the time of embedding, provided the concrete lie close to it and form an impermeable skin over it; it is, however, an important consideration to secure proper adhesion of the steel to the cement. Especially is this necessary in the case of wire which must not draw thru the cement in case an anchorage fails or it is rusted thru at one point. Galvanizing or painting the reinforcement is a pure waste of money and both are liable to introduce agents of corrosion, such as chlorides, metallic oxides and organic acids. A dip of tar-asphaltum would perhaps be beneficial.

Cinder concrete is more porous than that which contains a stone filler, and opposes less resistance to shear, and for these reasons it is less desirable in reinforced work; it is still a matter of some doubt if the small amounts of sulfur and iron oxide which are present in the cinder can have any effect worth considering on the reinforcement; it is, however, not advisable to use it around the reinforcement, especially where, as in the case of wire, "splitting" is to be avoided. For similar reasons it is best not to use slag cement until it has been definitely proved that steel is no more liable to rust in it than in genuine Portland concrete.

According to Breuille, if water is allowed to pass thru the concrete, the neat cement film in contact with the steel will disappear and rusting will take place; it is thus advisable to waterproof exposed surfaces—as is always done in the case of roofing—or to use an opaque reinforcement such as specially

crimped or corrugated sheets; even then the water, if it cannot go thru, will work its way out laterally.

Cement has been used for the inside of ships to protect the hull against the internal corroding agencies which are the most severe. Barges, pontoons and even row-boats have been built entirely of reinforced concrete.*

There is a great deal of literature published on the subject of reinforced concrete and the conclusions to be derived from it are that it is safe to use modern rustable steel reinforcement provided it is clean, and a coating of neat Portland cement on its surface is insured by using a rich and wet mix with clean sand and trap rock, limestone or other hard and passive filler, in immediate contact with it, and avoiding voids by careful tamping. The fact that concrete structures are monolithic and become stronger with age and also because the factors of safety allowed are—and should remain—conservative, we are justified in feeling convinced of their permanence, even if thru carelessness during erection the reinforcements suffer a partial decay. It would be unwise, however, not to provide against such decay and to allow it to go to the length of total destruction.

THE INHIBITION OF RUSTING

By the inhibition of rusting is meant its restriction or repression, not its complete prohibition; inhibition means an extension of life for the iron; the protective effect is, sooner or later, overcome and clearly indicates that inhibition furnishes *something* to the iron, be it substance or physical state, which, under the attacks of corrosive agencies is slowly expended until destroyed or brought below the safe limit of protection.

Inhibitory treatments have the effect of rendering the iron or steel passive. Passivity to chemical action may have a mechanical or electrical cause. In some cases it seems to be due to the formation of a neutral screen between the corroding agents and the iron; in other cases it seems to be due to a zone

*This system was first used for boats and pontoons by Lambot-Miraval, a Frenchman, in 1850. The manufacture of reinforced concrete skiffs, sailing boats, floating stages, pontoons and barges has been successfully carried out by Gabellini, of Rome, Italy, since 1897.

of occluded matter or gas which affords galvanic protection. This last seems to be the nature of the protection afforded iron which has undergone any of the inhibitory treatments which have so far been tried.

The fact, pointed out by Dr. Cushman, that treated iron will take on an adherent coating of copper from a sulfate solution in less than one-sixth the time required when it is untreated, is sufficient proof that the electrolytic action which causes the precipitation of the copper has been intensified by the inhibitory treatment; the difference of e. m. f. between the copper ions and the iron is greater. The investigator points out further that the protective effect can evidently not be due to a film of oxide ([58]).

That strong oxidizing agents would render iron passive, has been known for a long time. Prof. Bloxam in 1868 ([59]) showed that iron which had been dipped in pure nitric acid for a length of time was not affected by the same acid dilute. The fuming sulfuric acid will have a similar effect. Arsenic and its derivatives likewise inhibit rusting ([60]).

The best way to examine the subject of inhibition is to take advantage of the work of Dr. Cushman and analyze the following facts, exprest in his own words:

1°. "All substances which develop hydroxyl ions in solution, such as the alkalis or salts of strong bases with weak acids, to a certain extent inhibit, and, if the concentration is high enough, absolutely prohibit the rusting of iron."

2°. "No rusting occurred in any solutions of or above a strength corresponding to about 8 parts of potassium bichromate in 100 000 parts of water or about 2 lbs. to 3 000 gallons."

In both of these cases the objects treated were kept in the treating solutions. Potassium bichromate and chromic acid appear to be of benefit for retarding the inception of rusting, under proper conditions of concentration and condition of the surfaces treated.

(58) Cushman: Loc. Cit., pp. 21 and 23.
(59) Proc. Soc. C. E., Yr. 1868, p. 567.
(60) Lindet: C. R., Nov. 21, 1904.

3°. "No visible change is effected, for the polished surfaces examined under the microscope appear to be untouched. If, however, the polished strips are immersed in water, it will be found that rusting is inhibited for a matter of hours, days or even weeks."

The impossibility of detecting any change in the surface tends to show that no chemical alteration of the surface has taken place; the final overcoming of the protection by corroding agencies, shows that the attacks of those agencies exhaust the power accumulated by the treatment and that, therefore, some kind of destructive effect on whatever was left in the iron by the treatment, is taking place, until finally the metal loses its immunity and is corroded in the ordinary way.

4°. "If a polished surface, which has been rendered passive by immersion in bichromate, is heated to 100° C. for some hours, its passivity disappears and it again behaves in a normal manner."

5°. "A chromated strip of iron which is kept in a vacuum soon loses its passivity, whereas a similar strip kept under ordinary conditions remains passive for long periods."

These last two facts are strongly suggestive of the presence of an occluded gas, which can be baked out or diffused out in a vacuum.

6°. "The phenomenon of passivity is produced only by strong oxidizing agents or by galvanic contact when oxygen can separate on the iron."

As we have seen, when iron is anode and dissolves, it will rust, and hydrogen, which is negative to it, will be precipitated. In the present case we have the condition of oxygen being precipitated, showing that the iron is cathode. In the case of rusting we had free dissociated hydrogen inducing corrosion by its contact effect on the iron, now we have free dissociated oxygen inhibiting rusting by what we may well be allowed to surmise is likewise a contact effect. Hydrogen, which in itself is suggestive of reduction, is the *indicator* of the opposite reaction of oxidation, and oxygen, which suggests oxidation, is the indicator of reduction. This fact is very well

illustrated in the process of pickling by electricity ([61]), in which the metal to be pickled is put in a weak acid solution and connected as cathode in a circuit of low voltage; the scale is rapidly reduced.

7°. "According to Mugdan ([62]), the passivity is due to lowering of the potential of the metal."

8°. "If polished iron is allowed to stand for some time in standard tenth-normal potassium bichromate solution, the oxidizing strength of the latter, as measured by its titration value, is slightly reduced without the solution of the iron or the production of any visible effect."

This bears out the argument that oxygen is absorbed by the metal and that, being positive to iron, its contact effect is to render the iron immune as cathode so that it will not dissolve; the positive partner of the couple thus formed is the object of the attacks of the agencies which cause the rusting of iron. As we have seen, hydrogen in a free condition is "the enemy"; the inhibitory effect is therefore destroyed by the union of the attacking hydrogen ions to the oxygen in the surface of the treated iron. When hydrogen has combined with all the oxygen the iron has lost its passivity and rusting proceeds.

9°. "In order to show beyond doubt that an oxygen electrode is formed by immersing iron in a strong solution of bichromate, the following experiment was made: Two polished steel electrodes were prepared and chromated by immersion for a number of hours in a strong solution of potassium bichromate. The prepared electrodes were then thrust tightly thru a rubber stopper which closed a flask which was then filled with pure, freshly boiled distilled water. The electrodes were then attached to the poles of a primary battery of about 2 volts potential. At the end of half an hour, altho the potential was not sufficient to disengage bubbles of gas and no visible change had occurred, the electrode which was connected

(61) C. J. Reed's patent.

(62) Zts. f. Elektroch., vol. 9 (1903), p. 454.

to the zinc pole of the battery had lost its passivity, the other retaining it."

Rapid depolarization has here been effected by a reversal of current; slow depolarization, which finally does away with the benefits of the treatment, is brought about by natural agencies.

Cushman's conclusions are that from the evidence, the passivity of iron is best explained as a polarization effect produced by the separation and retention of oxygen on the surface of the metal and that the protection afforded by certain oxidizing agents is electro-chemical and not mechanical. That if the rusting of iron is due primarily to the action of hydrogen ions, iron in the condition of an oxygen electrode should be more or less well protected from electrolytic attack.

We have gone somewhat further and examined the growth and decline of this so-called polarization and the facts disclosed all go to vindicate the electrolytic theory of corrosion.*

*An extensive biliography of "Metal Corrosion and Protection" has been prepared by the Carnegie Library of Pittsburgh, copies of which may be obtained from the Librarian by forwarding two cents to cover postage.

THE CORROSION OF IRON AND STEEL

DISCUSSION

Mr. F. N. Speller: Mr. Sang has certainly brought this broad subject together in a very complete manner. There is only one point on which I would take issue with the speaker, that on the connection between solubility in acid and rate of corrosion. The history of this acid test started, perhaps, with the matter coming before the Committee on Corrosion of the American Society for Testing Materials, of which I happened to be a member. Whitney's experiments on the solution of iron had been repeated by Dr. W. H. Walker, Dr. A. Cushman proving that iron will go into solution without the presence of carbonic acid, and Dr. Cushman by his "Ferroxyl" test further showed in an interesting way that the electrolytic theory is the most rational explanation of the phenomena of corrosion.

It appeared to follow theoretically from this that the rate of solution in acid will be proportionate to the rate of corrosion. The point seemed so evident to some that it was decided to make mention of this method of testing corrosion in the report of this committee of two years ago. The precaution was taken, though, to point out that the fact noted had not been proved, that it was purely theoretical; the idea being to have a number of tests made at various places to aid which tentative specifications for making these tests were offered.

I had a talk over this matter with Dr. Cushman not very

long ago, but he now seems convinced that the acid test is not a reliable indication of the rate of corrosion for comparative tests. In conjunction with some others, we made some 200 tests on samples which had been previously corroded under natural conditions, and without going into details, I may say that only in a very few cases was there any connection whatever between the rate of solution in acid and natural corrosion.

The question of the effect of manganese, I think, is still open. No one so far as I know has offered any evidence to support the opinion that manganese in moderate amounts is going to increase the rate of corrosion. If precautions are taken as they should be to insure the uniformity of the manganese contents, there is absolutely no evidence to show that manganese in moderate amounts increases corrosion.

About two years ago I discussed the manufacture of tubes before this Society, and incidentally referred to the matter of the corrosion of modern tubes of charcoal iron and steel. At that time a certain number of results were given from laboratory and other tests which seemed to indicate that lapwelded steel tubes made under modern processes of treatment were somewhat superior to the older charcoal iron. It is hardly necessary to offer any more evidence along that line than what Mr. Sang has given, although I could go into details on a number of service tests that have been made since that time. We have complete service tests from thirty different railroads, made during the last two years, on charcoal iron and modern lapweld steel, which show that the steel corrodes more uniformly and somewhat less than iron. That is very satisfactory, and the National Tube Company has, as a result of a careful study of this question, concluded to abandon the manufacture of charcoal iron. What is required now is some reliable method of inhibiting or protecting metal from corrosion; this would seem to be the most fruitful field for discussion and experiment for the future.

The Author: I am very pleased, indeed, that Mr. Speller has given us some reliable information on the subject of the

ratio of corrosion under ordinary agencies and by acids. I have not found very much in the literature of the subject, but what there is would point to some ratio. In the course of ordinary laboratory investigations, I found that with pure acids there appeared, on the surface, to be some ratio. With commercial acids it is an entirely different matter. One never knows how they are going to act. One would have to know their exact composition and even then would hardly understand what was happening. But coming from an authority like Mr. Speller, new evidence is very valuable, indeed.

As to manganese, I think I said that if it is in very small proportions and evenly distributed it may not be detrimental, and that is my belief. But there are a great many very high manganese steels, especially wire, and I have seen some analyses which showed manganese very high and sulphur very high at the same time. Used for ordinary purposes, fencing, etc., I believe these to be highly corrodible.

Dr. K. F. Stahl: I can mention the following experience: We erected an addition to a building having corrugated iron sides, put on about 6 years before. The old corrugated iron from the original building was used again on the parallel side of the addition, while the two ends were covered with new corrugated steel. About eight years afterwards the steel sheets were badly rusted, but the older iron sheets were good yet. Both kinds of corrugated sheets were painted and repainted with the same paint at the same time. I blamed the manganese in the steel for the rapid oxidation, because I had observed a specimen of spiegeleisen, which I kept with minerals in an almost air-tight case, to rust badly. I did not make any experiments to verify this, but ever since when we bought corrugated sheets for siding or roofing, I specified iron, and demanded that the manganese should be below one-tenth of one per cent. We have used several carloads of these iron sheets in the last ten years, and they are all in good condition so far, much better than steel sheets purchased a year or two before we commenced to specify iron. Both kinds were repainted whenever they needed it.

I do not believe you can draw any conclusions from the way acids act on metals as to their ability to withstand rusting. When it comes to acids I don't think there is any difference between iron and steel. In tanks used for storing or transporting sulphuric acid, our experience seems to indicate that iron will last about the same as steel. Our older tank cars are all iron and the newer ones steel. Not long ago we dismantled an iron tank car, which had been in service about twenty years, mostly for 66° sulphuric acid. From time to time it had required repairing, a little hole would appear which we soldered up, and the car would run for six months or more before another hole appeared. After we dismantled it, I went inside and found that it was eaten in streaks; there were grooves in it running parallel and close together 1/16 in. deep, some as deep as ⅛ in. Finally, some of these grooves got so deep that they caused a leak, sometimes as small as a pin hole, which could be stopped with solder, the surrounding metal being quite strong. Quite a number of the steel tanks which I have examined have been eaten almost uniformly. We are dismantling a storage tank where the steel sheets are probably only 1/16 in. thick all around, they were ⅜ in. originally. This is a large tank, built only about ten years ago. It was used for 60° acid, which is probably more destructive to either iron or steel than 66°, and as the acid is pumped in and withdrawn daily there is more agitation and consequent action on the metal than in a tank car. Iron tanks may have parts that are still ¼ in. thick and other parts that are eaten almost through, therefore, while more metal is dissolved in a steel tank than in an iron tank, they will probably need renewal after the same length of service. The rivets seem to go faster than the sheets. We have had any number of rivet heads eaten off entirely, so that the rivets could be pushed through with a slight tap of the hammer. This proves what Mr. Sang said, that stresses in iron tend to make it acted on more quickly and that if parts of a tank are of different composition, galvanic action will set in.

The Author: As to the different behavior of iron and steel sheets, I would point to a very well known fact, that when it

comes to painted sheets it is very difficult to judge, because iron takes the paint very much more readily than steel and that vitiates the conclusions. As to the case of the iron tanks corroding in streaks, that was due to the slag that was rolled out. That is the way iron sheets usually corrode. If we had a piece of that sheet, I think we could find the culprits.

Mr. R. B. Woodworth: My investigations on this subject are rather towards the prevention of corrosion than a study of corrosion itself. The problem that confronts me as an engineer is, given structural steel as it is and the workmen as we know them to be, what can we do to prevent corrosion and to lengthen the life of the steel?

We all know that corrosion takes place under certain conditions, that impure river waters, saline waters, waters carrying more or less high percentages of sulphuric acid, soils containing deleterious mineral ingredients, all have more or less corrosive qualities. These conditions we have to meet, and I am very glad that this problem has been brought before the Engineers' Society of Western Pennsylvania and that my own investigations into the prevention of corrosion will have the assistance of so careful a paper as the one to which we have listened this evening.

One of the most interesting facts in connection with recent researches into the corrosion of iron and steel is that our friends, the paint makers, have been compelled to take an intense interest in the subject and to set on foot investigations into the chemical and physical properties of the materials which they furnish for their own protection against unwise legislation, ultimately designed to insure the obtaining by the consumer of a pure product. I venture to predict that some of these days we will be able to buy paint just as we buy steel, subject to specifications as to quality, and that each can will be labeled with its chemical composition and that we will thus be enabled to obtain mixtures of which we will know, before their application, that the results will be in accordance with our desires. In the course of the investigations that I have been making on paint for the protection of steel mine timbers

exposed to sulphuric acid laden waters, I have had occasion to ask a number of paint manufacturers for some information as to the exact chemical composition of their paints as sold in the open market. I have been unable to obtain from them any information of this sort, and so far as I know there is only one paint manufacturer in these United States who is willing to tell you what he actually puts into his product. That being true, the proposition to a man who has to paint a particular piece of steel work is not very simple.

It may be interesting to state that I have in my possession a piece of iron that was put into the Mississippi River in the year 1863, and that is to-day in as good condition as when it was put in. It was painted with some kind of red paint which looks very much like red oxide of iron, and the paint is just as good to-day apparently as it was the day it was put on. The conditions there must have been extremely favorable to its preservation. The water of the Mississippi River at that point is probably pure and the iron was buried in the Mississippi River silt, sand or gravel so as to be protected from exposure to atmospheric conditions, and as a consequence there was nothing to make corrosion.

I have also a theory that so far as our own rivers are concerned, although they do carry a great deal of free acid, yet when the steel is placed sufficiently below the river bed as to get the advantage of the filtering action of the sand and gravel, we do not have to do with an acid laden condition, but rather with the condition of practically pure water free from contact with air, and I think we have every assurance to believe that the life of steel under such circumstances will be indefinite. I was told by the engineers who have charge of the construction of the Black Rock Lock at Buffalo, that the waters of the lake are not considered in any way dangerous and that steel of ordinary commercial quality in such installations may be expected to last for any reasonable length of time.

It may be interesting in this connection to refer to the characteristics of the different waters with which we have to deal. In looking up the subject, I have been very much sur-

prised to learn that river water does not contain any such large amount of free acid as I had supposed. The data, however, has not been gathered very completely, and it is possible future researches may give us more complete information. According to a report made by the United States Geological Survey, the Youghiogheny River at McKeesport during the year from September 6th, 1906, to September 6th, 1907, carried but 75 parts in a million of free sulphuric acid. At Elmira, N. Y., the Chemung River carries a proportion of total solids of 76 parts in a million composed of nitrates and chlorides without a trace of sulphuric acid, and with 500 to 26 500 bacteria in a cubic centimeter. Just above the anthracite basin, the Susquehanna carries 113 to 166 parts of total solids in a million composed of nitrates and chlorides and 1 980 to 2 750 bacteria in a cubic centimeter. The same river at Steelton carries 110 to 200 parts in a million of nitrates and chlorides, with bacteria running as high as 186 000 per cubic centimeter. Now, the presence of bacteria in river water means in a general way the absence of free sulphuric acid, for the two are not very friendly to each other, but there is a stretch of water between Steelton and the upper end of the anthracite basin where the water is entirely different and where the conditions so far as preservative treatment is concerned are quite serious. In this section the river from Nanticoke down receives the runoff from the mines, but farther down the effect of the different chemical constituents is to act as a coagulant with the deposition of the suspended coal and sulphuric acid bearing solids and consequent clarification of the stream. Three analyses of water run as follows:

No. 1—Total solids	792	parts in a million
	39	parts sulphuric acid
	79	parts iron oxide
No. 2—Total solids	1977	parts in a million
	150	parts sulphuric acid
	393	parts iron oxide
No. 3—Total solids	3003	parts in a million
	164	parts sulphuric acid
	143	parts iron oxide

I mention these figures only to show that each particular condition of the probable corrosion of steel would necessitate a different treatment, and it would be wrong to argue that the method used in one place will be sufficient for another, or that a method which fails under one condition is not, therefore, to be condemned for a different locality.

The deleterious action of mine water is due not only to the free sulphuric acid contained therein, but probably also to the amount of iron which it carries; all of which comes from the decomposition of the coal itself. Coal may contain sulphur in three forms, viz., as sulphate of lime, as sulphide of iron, or iron pyrites and possibly as organic sulphur. More commonly the drainage from the mines comes out in the form of protosulphate of iron, $Fe\ SO_4$. On exposure to the air this salt, according to my authority, breaks up yielding hydrated oxide or free basic sulphate of iron which precipitates and gives a yellowish color to many of the waters of the small streams into which the mine drainage runs and sesquisulphate, or ferric sulphate, which remains in solution. This ferric sulphate, when brought into contact with metallic iron or steel, attacks it freely, and the metal is converted again into the protosulphate of iron. This in turn breaks up and the corrosive action repeats itself in the continued series until the supply of iron is consumed. In this way the corrosive action continues indefinitely and the formation of rust carries with it a continued increase of rusting surface and of rust making power.

The same condition is that which confronts us in the matter of scale in boilers, which is taken care of, in some cases at least, by the addition of soda ash in quantities sufficient to a little more than react with the ferric salts, and, when carbonates are present in sufficient quantity, to neutralize the action of the free acid; corrosion is practically out of the question, and the decay of the steel effectively prevented.

These are the conditions with which we have to deal and the problem for the paint manufacturer and the engineer is: Given a structural steel, which the world has looked upon for years as a standard material for all kinds of ferric structures,

and given unskilled workmen who put on preservative coatings on that material without especial care in its proper preparation, what will be the result of our endeavors and how can we best accomplish our purpose in making of that steel a permanent structure? There are two lines along which the solution will probably be reached. First, we may arrive, by our investigations, at a preservative material which will inhibit corrosion, but whose expense may be prohibitive. Dr. Cushman has told us that chromic acid is one of the chemical constituents which we can apply with beneficial results. Another and probably the more economical solution is to take pigments easily within reach and protect the material by some ingredient, such as red lead, which will adhere firmly and tightly to the steel, and then to protect that pigment by a second coat, or a third coat, which in turn is not attacked by acids.

Mr. J. S. Unger: My experience is that the addition of about 3¼ per cent nickel to a carbon steel reduces its corrosion by the action of solvents to much less than what it originally was. In some experiments we made we used three varieties of wrought iron, two of basic open hearth steel, one of Bessemer steel and one of nickel steel. We subjected them to various agents such as sea water, 10 per cent solution of boiling brine, 1 per cent solution of sulphuric acid and 1 per cent of ferrous sulphate, made to imitate a mine water, and the action of ordinary well water, or water that contained no free sulphuric acid, but contained carbonates and sulphates of lime and magnesia.

We found after treating them in the solvents for about a year, the actions ranked in about this order: Common pipe wrought iron was corroded the most, then a medium quality wrought iron, followed by a low carbon Bessemer steel; then by the best grade of wrought iron, then by open hearth steel, each of the open hearth steels being corroded to about the same extent. The material that was least corroded was open hearth nickel steel. Our object in testing the open hearth steels was to determine whether open hearth fire box steel of high or low manganese would show a difference in corrosion.

The plates under examination carried about 0.22 and 0.60 manganese. In the tests they were subjected to, we found very little difference. The carbon, phosphorus and sulphur contents were about the same in both plates, the difference being in the manganese. Further experiments along this direction led me to believe that the more impure the substance the more rapid the corrosion, or, in other words, the Bessemer steel will corrode more rapidly than open hearth steel; an acid open hearth steel will corrode more rapidly than a basic open hearth steel. Wrought iron, being a different sort of material than steel, some of the phosphorus and some of the sulphur possibly existing in two states, as that of sulphite, sulphate, phosphite, phosphate and sulphide or phosphide; they are heterogenous substances and it is difficult to draw a real conclusion from them. But we have found that in almost all cases the wrought iron will corrode more rapidly than steel. We have also found that on comparing high and low carbon steels made by the same process, such as high and low Bessemer or high and low basic open hearth steels, that the higher the carbon, other things being equal, the more rapid the corrosion.

I believe there is a current belief that wrought iron pipe and wrought iron roofing will last very much longer than steel. We carried on what might be called some practical experiments, completing them just a few months ago, but not with quite the accuracy of the preceding experiments. The experiments were as follows: We took two sheets each of several corrugated roofings, standard size, of as near the same gauge as it was possible to secure in the market, carefully polished, analyzed and gauged them, and placed them side by side on the roof of a mill building. There was a possibility of galvanic action between the sheets, but that was disregarded. The sheets were not covered with any protective agent. They were in a bad location where they would get the benefit of any gases coming from the heating furnaces and the exhaust steam from an engine. They were allowed to remain about three years when they were removed. At the expiration of that time the results were as follows: The three brands of wrought iron

of two sheets each had corroded until they were almost ready to remove. Some portions, especially where they lapped, had been corroded until they were almost like a net work and could be broken through readily by the pressure of one's fingers. On the high portion of the corrugations we found the wrought iron sheets still strong enough to resist a slight pressure; on the bottom of the corrugations they were practically corroded through. Of the steel sheets tested at the same time, and which were in fair condition, we found on analysis that what had been sent to us as open hearth roofing was really a moderately low phosphorus, low sulphur grade of Bessemer roofing; but we found that the three grades of steel roofing on the roof at the time, were better preserved than any of the wrought iron roofing. Further, it was noticeable that in the steel roofing the corrosion was uniform over the entire surface, while the iron roofing tended to corrode in streaks and spots. I had the slag determined in the three grades of wrought iron roofing. I supposed the sheets with the largest proportion of slag would be the least corroded. Unfortunately, it was attacked first, and was the poorest variety of the lot. Our slag determinations were really more in the nature of a determination of insoluble matter and not of oxides. I believe that in addition to the actual amount of insoluble slag in the material, consideration should be given to the amount of oxides that existed in the wrought iron. There are certain oxides which in the ordinary determination might go into solution and not be caught in the filter, and yet might exercise a protective influence on the material.

I confirm Mr. Speller's statement that the atmospheric corrosion tests will not compare with the acid solvent tests. In order to secure results quickly, one must adopt an acid test. The amount of time required is too long in a great many cases if less than a 5 per cent solution of acid be used for the tests. If one has the time he can work with a 1 per cent solution of sulphuric acid, but unless the solution is made extremely dilute, one does not get results that are at all comparable with the action of, say mine water or ordinary river water. I

believe the differences secured in results have been due entirely to the strength of the acid that was in the solution, a very dilute sulphuric acid seems to act more nearly like atmospheric conditions than a more concentrated one.

Mr. Whited: I notice that the railing on the city bridges rusts more rapidly than any other part of the bridge, that is, above the roadway, particularly when the sidewalk is paved with asphalt or floored with wood. I suppose that is due, in the case of asphalt, to the fact that the asphalt shrinks away from the steelwork, allowing the accumulation of filth, thus forming a center from which voltaic action starts and extends rapidly in all directions. In the case of wood, I suppose the acid in the oak, which is the usual material for bridge floors, starts corrosion, which is extended in the same manner as in the case of asphalt. Where cement sidewalks are used, the cement adheres closely to the steel and prevents the accumulation of filth and the above-mentioned action does not occur. Still, the railing rusts even then, more rapidly than the upper parts of the trusses. I suppose that is partly due to dirt from the hands and clothes of passers-by, and partly to the fact that most of the railing manufacturers use poor paint in their shops.

I would like to ask Mr. Sang if he can give us in detail the recipe which he says is used on the French railroads to protect their overhead structures, or at least give us a reference to it?

The Author: I am sorry to say I cannot give the nature of the mix, but I shall be pleased to furnish the information from the source from which I got it, and it can be inserted later.*

By a Member: You spoke of arsenic inhibiting corrosion. How much is it necessary to put in steel?

The Author: The arsenic was applied as arsenious acid in those tests made in France, and there was no evidence as to the amount absorbed. The arsenic was not in the composition of the steel, it was an application as in other inhibitory treatments.

*Original not available. See "Engineers' Hand Book of Concrete Reinforcement," American Steel and Wire Co., July, 1907, p. 36.

Mr. G. E. Flanagan: Mr. Sang, in his paper, laid stress on the necessity of getting very intimate contact between the cement and the steel in reinforced concrete. Most all of us have heard the same thing before, and it is well that we should hear it again, and be reminded of it frequently, lest we forget. There is probably no more vital feature in the whole problem of reinforced concrete construction. It seems strange that people in the present day engage in constructing such work and act as though they were oblivious of this fact, but many do. They seem to think, when they have the various special types of bars for armored concrete, which change the form of their section continually, or at least in a distance of 2 in. or 3 in., that the adhesion of the concrete to the armor is less vital. It would be well if that sort of notion could be entirely eradicated from those who have this work to do. I also noticed in the paper that the question of whether the bar is rusty when it is put in place has very little effect on the further progress of the rust on the steel. There are some very good builders of armored concrete who refuse to take bars as they come from the mill, but insist on their being exposed to the weather for a time in order that the bars may become rusted, as they claim that the cement secures a better adhesion than if the bars come fresh from the mill with the black scale upon them.

Mr. James O. Handy: The following data, from the records of the Pittsburgh Testing Laboratory, showing the superior resistance of a very pure iron sheet to corroding influences, may be of interest:

	G. C. Iron Sheet	M. C. Steel Sheet
Carbon	0.018%	0.09%
Manganese	0.024%	0.39%
Phosphorus	0.040%	0.103%
Sulphur	0.023%	0.053%
Silicon	0.036%	....
Corrosion ratios:		
Cold sulphuric acid (3.6%)	100.	1600.
Air and moisture	100.	280.
Sulphur dioxide and moisture (cold)	100.	112.
Sulphur dioxide—strong solution in water	100.	108.

These tests show that in mine water the iron sheet would last much longer. In air it is superior to steel, but in a less degree. It resists the attack of sulphur dioxide but little better than steel. The air and sulphur dioxide tests are most rational for materials of construction.

FAILURE OF CAST IRON FROM ELECTROLYSIS

Two cases have recently been investigated by us. The cause of failure was not known at first. The iron had apparently remained of the original thickness, but had become soft like compressed graphite or stove polish in consistency and appearance. The failure occurred only in isolated spots. Analysis showed that half to two-thirds of the iron had gone, leaving the remainder as a black hydrated oxide. The carbon, phosphorus and silicon remained in their original ratios to each other. No other explanation than that of electrolytic solution of the iron is tenable. One case was that of a brine pump used for circulating calcium chloride solution in a refrigerating system. The other was a water main failing only in spots after 16 years' service. There was no rusting. The iron had been abstracted by weak electric currents assisted by saline matter in solution.

Mr. R. A. L. Snyder: The Telephone Company are vitally interested in the subject of corrosion. We have a great amount of metal surface exposed to the action of corrosion, both aerially and underground. Our messenger wire, cable clips, line wire, etc., are continually deteriorating. A large number of experiments have been made in our laboratory and the conclusions reached are that electrolysis is generally responsible for corrosion. After trying numerous combinations of metals and forms of alloys and coatings, the best combination we have been able to find is a zinc coating on iron (galvanizing). Zinc is electro-positive to the iron and when you scratch through the zinc coating it appears to be self-healing, i. e., the current seems to plate the zinc over the iron again. Tin-coated iron exhibits the reverse action, tin being electronegative at the abrasive point. The iron not only rusts very

rapidly, but the rust usually extends under the tin coating. Corrosion is such an extensive subject that it deserves most careful study. I believe there will be something developed in the near future which will give a better protection for iron than the present galvanizing or metallic paints.

I would like to ask Mr. Sang if he has ever taken a piece of iron embedded in concrete and placed it in water, making the iron anode and the water the cathode and passed a small amount of current through it to see if it corrodes the iron. I tried this experiment and found that the iron corroded quite rapidly, but I do not know if I had the proper mixture of concrete for this class of work. I have always been rather skeptical as to the thorough prevention of corrosion in structural iron foundations set in concrete, especially if they are positive to the earth. To protect plunger elevator casings, which extend several hundred feet into the earth, we have taken the precaution to make them electro-negative to ground. I believe that the subject of electrolytic corrosion in its various forms is not appreciated by many engineers.

The Author: I have never tried the experiment referred to. I suppose you all know that it has been tried and is still being tried, to put large masses of zinc in the foundations of the steel work of skyscrapers. I have heard of it being done, but I never have heard the result. Perhaps our children will know about it.

Mr. H. S. Prichard: The writer listened with great interest to Mr. Sang's highly instructive address. The author has based his paper on such profound knowledge and treated his subject so comprehensively, that not much can be properly urged in criticism, and very little can be added to the information he has given. It is only where he departs from his theme, corrosion of iron and steel, to commend the superior virtues of reinforced concrete over other forms of construction, that the writer desires to take issue with him. Reinforced concrete has reached a high rank as a building material and occupies a wide field of usefulness whose boundaries have not yet been definitely determined, but, quite apart from beauty of form, it has

not proved itself the best for every purpose and from all points of view, as the author considers.

After pointing out the value of cement as a protection against rust, the author does well to call attention to the fact that concrete is not a complete protection, and the writer would emphasize this point as there is a tendency toward over confidence in this regard.

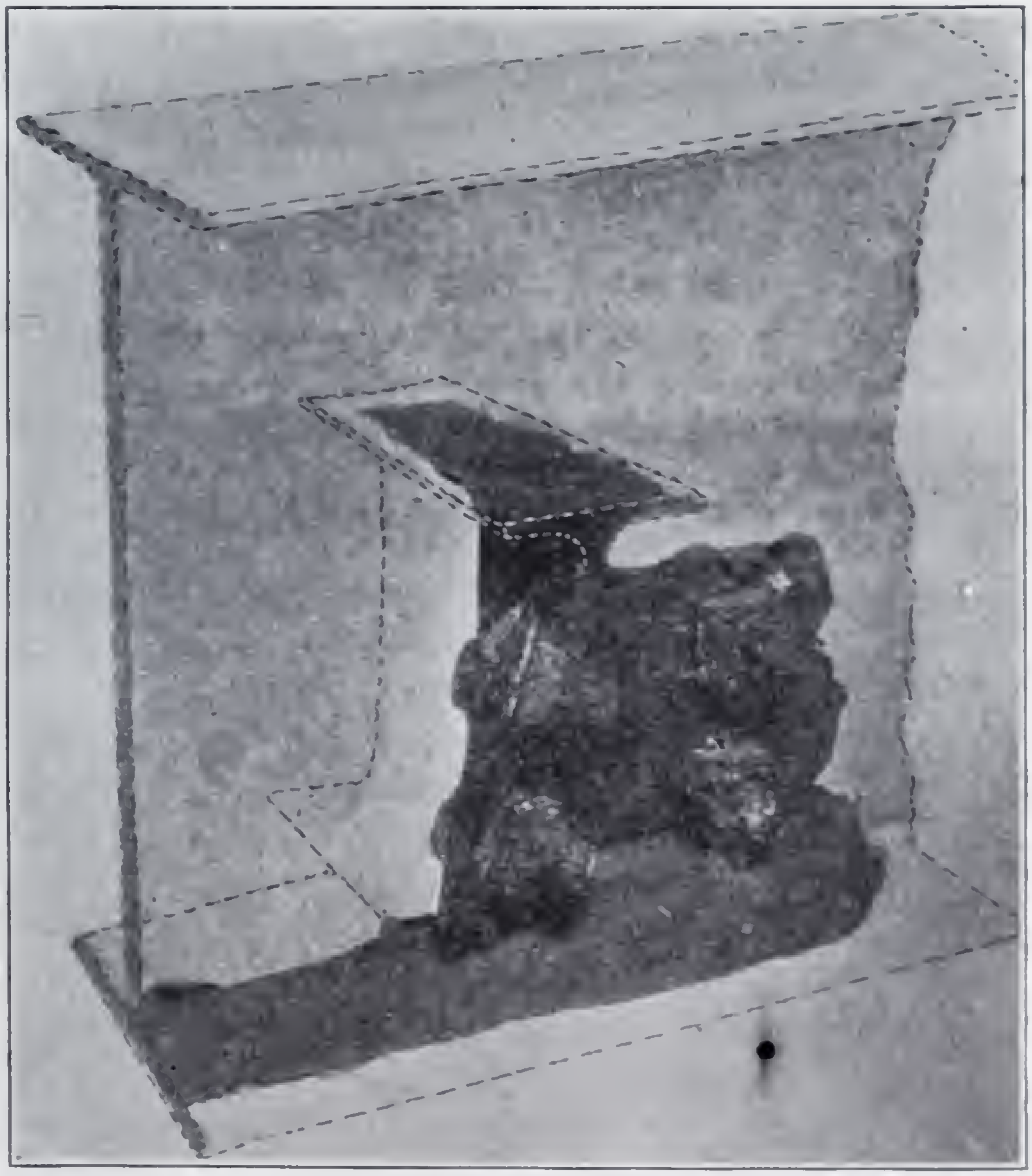
J. A. Fitzpatrick, in Scientific American of Nov. 28, 1908, p. 373, calls attention to the rusting of beams in the basement floor of the Eastern Power Station of the Brooklyn Heights R. R. at Kent and Division avenues, Brooklyn. According to Mr. Fitzpatrick, "the basement-floor construction consisted of 6 and 7-inch steel I-beams framing into 15-inch steel I-beam girders. Between the beams were segmental concrete arches, stiffened by a wrought-iron mesh center. These arches did not cover the bottom of the beams, but left the flange exposed except for an occasional coat of paint received in the early history of the station. The steel frame was erected by the Berlin Iron Company in 1890.

Considerable rust was noticed on the exposed beam flanges; and as some of these appeared to sag in the center, a section of arch was removed, to see the condition of the upper portions of the beams. In only a few cases was there any upper portion left, the steel having corroded to such an extent that the webs and top flanges had disappeared entirely, leaving only rust on the adjoining concrete. The floor, instead of being supported by the steel framing, was in reality carried by the three-inch slab of concrete covering the tops of the arches."

Mr. Fitzpatrick further states that he "investigated the locality, finding the following conditions to exist:

The condensers employ salt water in their operation, and much of this is ejected in the form of spray on all sides of the condenser pits. There being no chance of drainage, this has been allowed to settle for years in pools on the floor, and together with the exhaust steam from the engines above, which found its way into the cellar, the atmosphere in the space between the two floors was kept continuously moist. This mois-

ture was absorbed by the concrete arches, and held as if in a sponge, close against the web and upper flanges of the beams. The decomposition was probably slow at first; but as the chemical action progressed, a space was made between the steel and the concrete, leaving a space for air to enter, thus accelerating the chemical action. The exposed bottom flanges were in far better condition than the inclosed portions of the steel, this probably being due to the paint they received.



The wrought-iron bolts throughout the work were in an almost perfect state of preservation. This was also found to be true of the wrought-iron mesh centers under the arches.

The illustration reproduced here shows typical examples of the 6 and 7-inch beams framing into the 15-inch beam gir-

ders. The steel being worn to a knife edge on the flanges, and the small portion of webs remaining, evidently show the effect of electrolysis.

The almost perfect preservation of the bolts is also shown, and it will be noticed that the shop rivets are in better condition than the material in the beams. The bolts, as mentioned before, were made of wrought iron, but the rivets were of rather soft grade of steel, while the beams were of the hardest grade of steel that the writer has ever seen used in construction work. This leaves an open question as to whether the hardening elements in the high-grade steel, carbon and manganese, did not assist in the decomposition.

The main sewer draining the residential section of Williamsburg flows past the station on the north side emptying into Wallabout Creek a few feet away from the mouth of the intake tunnel which supplies the water for the condensers. Traces of chlorine have frequently been detected in the basement, and this has undoubtedly assisted in the decomposition of the beams."

The rusting of steel beams, under the circumstances described by Mr. Fitzpatrick, shows that concrete is not complete protection, and indicates the need of judgment in the operation of power and manufacturing plants, and in deciding on the construction to be used when water is liable to stand or play on the floors or walls of a structure, but for the ordinary run of buildings in which combinations of concrete and steel are not liable to be water soaked, it does not have much bearing on the question with which Mr. Fitzpatrick's article is headed, viz., "Is Concrete Steel a Permanent Construction?"

Stripped of technical phraseology, it may be said that combined moisture and air in contact with iron and steel is the prime cause of rust. It is, therefore, very important, in designing iron and steel structures and frames, to avoid, as far as possible, places where water or refuse can collect, and to arrange any metal, not permanently embedded in some protective material, so that it can be readily inspected and repainted on occasion.

Mr. J. A. L. Waddell, in a paper on "Nickel Steel for

Bridges," which was published in the September Proceedings of the Am. Soc. of C. E., gives, on pages 737 to 739 and 883 to 886, the results of two sets of comparative corrosion tests of nickel, and carbon steels; one set made by himself and one made for him by the Osborn Engineering Co. In the cinder and locomotive gas tests, nickel steel showed the greater resistance to corrosion. In the salt test by Mr. Waddell, nickel steel showed decidedly the greater resistance, while the salt test by the Osborn Co. nickel steel showed slightly greater resistance up to 870 days, but carbon steel showed slightly greater resistance at the end of 900 days, when the test was discontinued. In the sulphuric acid test by Waddell, continued 160 days, carbon steel showed decidedly the greater resistance, while in the test by the Osborn Co., continued for 900 days, carbon steel showed only slightly greater resistance to corrosion.

The Author: In Mr. J. A. Fitzpatrick's article, quoted by Mr. Prichard, it is not mentioned whether the cement used was a natural or a Portland cement. From the date (1890) the chances are that it was a natural cement, which is not suitable if permanent qualities are to be secured. In my paper I very distinctly refer to *Portland* cement. Mr. Fitzpatrick does not give the physical condition of the concrete as he found it, and especially where it came in contact with the I-beams. It is difficult to judge, therefore, whether or not the work was properly done. Even with the best of cement and the best of steel, permanent qualities cannot be expected if the work is improperly put up. This is true of every process in engineering, and I do not think that the data furnished by Mr. Fitzpatrick is sufficient evidence that concrete steel is not a permanent construction. Where water or any corrosive liquids or gases are present, there is necessarily great danger of these liquids or gases seeping through the concrete and attacking the reinforcement. Under such circumstances it is poor judgment not to protect the surface of the concrete by some special treatment, as I pointed out in my paper. The qualities of reinforced concrete must be judged under normal

conditions; when conditions are not normal it is evident that special precautions must be taken.

Mr. R. A. Cummings: The engineering profession should be grateful to Mr. Sang for the careful manner in which he has presented this important subject. Every engineer has to do with some sort of a structure using steel, so that the information will appeal to a large number. To those identified with reinforced concrete construction, his assurance of the permanence of the reinforcement will be especially appreciated.

It is regrettable that his observations of the neglect of engineers to consider the corroding of steel in concrete should have been confined to the work of those who have doubtless been governed by indifference or commercial conditions. Nevertheless, the practice of the writer is to take precaution against the corrosion of the reinforcement. Wherever reinforcement is embedded in concrete that is submerged in water or subjected to moisture, the rods are completely coated by immersion in a bath of neat Portland cement immediately before being placed in the work. Portland cement is strongly alkaline and it has been stated in the paper that alkalis "absolutely prohibit the rusting of iron."

In addition to this statement, it is a fact that there are innumerable examples in existing works of complete prohibition of the rusting of embedded steel. Reinforcement, therefore, merits the full confidence of practicing engineers in the permanence of the steel reinforcement.

The accuracy of the statement in the paper preferring sheet metal to the many styles of reinforcement must be questioned, as it is not clear what is meant. It is doubtless true that the deformations of twisted and other irregular shaped rods is liable to cause air pockets to form around the reinforcement or to prevent an intimate contact with the concrete. But it is claimed by the venders of deformed rods that such occurrences are negligible owing to their mechanical bond obtained. Nevertheless, the writer would urge the use of plain rods of a uniform circular section as such rods offer no obstruction. Concrete in setting will shrink radially towards the surface

of a circle and grip the rods so the adhesion is all that good practice can demand. On the contrary, concrete does not adhere to a flat surface, but will arch itself and shrink away, leaving a space without contact with the sheet metal, plates or structural steel.

Galvanizing and painting with oil or tar must be avoided as defeating the adhesion of the concrete to the rods.

There is an immense amount of technical detail in connection with the design and construction of reinforced concrete which must be intelligently applied and conscientiously carried out.

DISCUSSION OF PAPERS.

Members of the Society and also other readers of the Proceedings are urged to send to the Secretary written discussion of papers after publication, which will be printed in succeeding issues of the Proceedings. We believe that much valuable information may be presented in this way, and it is hoped that this feature of written discussion may be made a prominent one in the Proceedings.

INSPECTION TRIP

TO THE

DUQUESNE STEEL WORKS

One of the most enjoyable excursions of the year took place on the evening of Friday, December 18, 1908, when about 250 members of the Society and their friends were the guests of the officials of the Duquesne Works of the Carnegie Steel Company. The party left Union Station in special cars attached to the 7:20 P. M. train, and arriving at Oliver Station, were received by officials of the company, who escorted them thru the works over the following route:

The No. 2, 13-inch mill, and the No. 4, 10-inch mill, were first visited, where the operation of the continuous mills was of much interest. The billets are fed into the heating furnaces at one end, and, after passing thru the furnaces, enter the first of a series of trains of rolls, the velocity of which increases in relation to the reduction in area of the section as it passes thru from one set of rolls to another. The finishing passes are given in other trains of rolls, where the hot bars are handled by hand.

The party then viewed the twisting machines, which twist square bars cold for use in reinforced concrete work. The twisting is done in a machine, the bars being firmly clamped at one end in a stationary head, and fastened into a chuck at the other end, which is driven by a 50 H. P. electric motor. The number of twists in the bar is indicated by a register which indicated to the operator when the process is complete. The bars are from 3/8 in. to 1 1/2 in. square, the size varying according to the work for which they are intended.

One of the interesting processes witnessed in the No. 1, 14 in. mill, was that of shearing hot bars as they come from the rolls without retarding their progress. These shears consist of a swinging arm supported on a pin located some four or five feet under the floor. The shear blade is hinged to a

head moving in slides at the upper end of the swinging arm, so arranged that the blade can swing outward in the direction in which the hot bar is traveling. The shearing is accomplished by means of a steam cylinder, and while the shear blade is biting into the material, the arm containing the blade and its carriage swings on the pin, carried along by the traveling bar. As soon as the blade has passed completely thru the bar, by which time the swinging arm has reached its extreme point of travel, the blade is pushed out by the end of the bar coming from the rolls, allowing it to pass thru the opening in the swinging shear, which now assumes its original position, ready to repeat the operation, which is gauged automatically to shear the length of bars required.

The next point of interest was the chemical laboratory, where Mr. J. M. Camp, Past President of the Society, and his corps of assistants received the visitors, and explained the various apparatus used in their work. Leaving the laboratory, the party passed thru the open-hearth department, witnessing the electric charging machines in operation, and the electrically operated strippers, which strip two ingots from their moulds at one time, and which have replaced the hydraulic machines formerly used.

The principal feature of the evening was the inspection of the new twin tandem, compound, reversing mill engine, recently designed and built by Mackintosh, Hemphill & Company of this city.

The fact that the president and mechanical engineer of this company are members of the Engineers' Society of Western Pennsylvania added much of the personal element to the interest displayed by visiting members in this latest addition to the more important achievements of Pittsburgh's engineers.

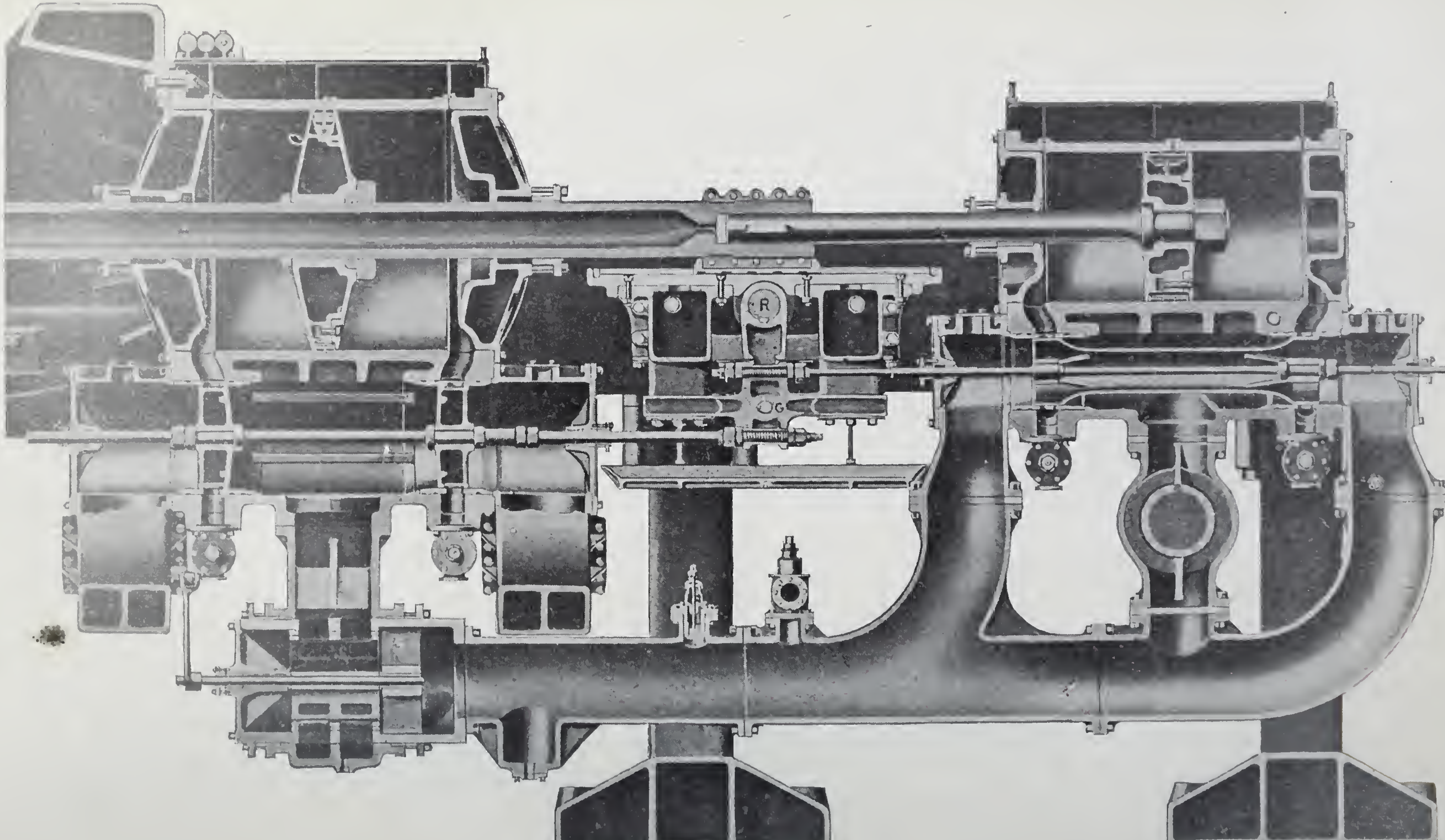
The engine is direct connected to a 40-inch blooming mill, and in addition to being probably the largest and heaviest of its type yet built, presents some radical departures from the usual standards of design for this type of engine, which make it especially noteworthy. The twin engines are 44 and 70 by 60, designed to run at 100 to 150 r. p. m., and at 100 r. p. m. will develop 20 000 H. P.

The use of piston valves, placed directly beneath the cylinders, is the most radical departure from usual practice; the valves being located in this position to secure perfect drainage of the cylinders. As rolling mill engines are, at times, at rest for long periods, considerable condensation in the cylinders may result, and with this construction natural drainage is secured into the valve chamber and thence into the exhaust; the water collecting in the receiver being removed by suitable steam traps. This feature is in marked distinction from designs with valves above or along side the cylinders, in which cases the sudden starting of the engine might easily result in cracked cylinder heads or other breakages thru an endeavor to force the water of condensation thru the exhaust ports. The cylinder clearance is reduced to a minimum by placing the valve chambers as close as possible to the cylinders, which brings the center lines of the chambers on different elevations. The construction is clearly shown in Fig. 1. The valve rods are actuated by a slide block, G, which receives motion from an arm attached to the rock shaft, R. The rock shaft is driven by the eccentric connecting rod to which it is attached by a single link as shown in Fig. 2. To secure a straight line drive, three eccentrics are used for each half engine, the two outer eccentrics operating one end of the links, which are of the Stephenson type, counterweighted, with variable cut off.

The valve gear has evidently received unusual attention from the designer, as the number of moving parts in the entire driving gear has been reduced to two rock shafts and six pins.

The reversing mechanism is of the standard steam driven type, using a cataract cylinder filled with oil to lock the various positions of cut off. The valves are operated by a floating lever.

The steam connections shown in Fig. 3 are of especial interest. From the engine side of the balanced poppet type throttle valve, A, a connection, B, leads to another balanced poppet valve, C, which is controlled by levers from the operating platforms. Thru this valve, C, live steam may be admitted to the receiver, E, when required, thru the pressure regulating valve, D. When the engine is standing idle the



SECTION THRU CENTER LINE OF CYLINDERS

FIG. 1

valve, C, is opened from the operating platform and valve, D, immediately controls, automatically, the pressure in the receiver, maintaining same at the discharge pressure, under running conditions, of the high pressure cylinder. This feature of design maintains at all times a proper pressure of steam in the receiver, compensating for all condensation losses, so that the low pressure cylinder is enabled to carry its full share of load immediately on starting the engine, obviating entirely the necessity of running the engine until the receiver pressure is built up, as in the usual design.

In order to shut down the engine quickly, stop valves, shown at S in Fig. 1, are placed at the inlet to each low pressure valve chamber, which are actuated from the operating platform simultaneously with the throttle valve, thus cutting off steam from both high and low pressure cylinders at practically the same instant. Without this auxiliary valve, S, the engine would operate for a few revolutions after closing the main throttle, due to the volume of steam in the receiver, with resulting delay in operation and consequent reduction in output of the mill.

The simplicity of design and exceptional accessibility of parts were apparent to all visitors, and these features, together with the massive design and remarkable smoothness of operation in reversing incited much favorable comment. During the evening while the engine was running under load conditions, a number of pennies were balanced on edge at various points on the front end of the engine frame near the cranks. The total absence of vibration in the engine was shown by these pennies remaining in a balanced position during reversal and quick change from light load to heavy load.

The general features of design are apparent from the accompanying illustrations. The crank shaft is forged steel 29¼ in. diameter with a 6 in. axial hole running its entire length. The main bearing on the left hand engine is 29 in. by 48 in. with crank pin 19 in. diameter by 14 in. long. The right hand engine has two bearings 29 in. by 44 in., the crank pin being 27 in. diameter by 17 in. long. Both cranks are counterbalanced. The forged steel connecting rods are 13 ft.

9 in. long. The marine type rod on the right hand engine carries two nickel steel bolts 7¾ in. diameter.

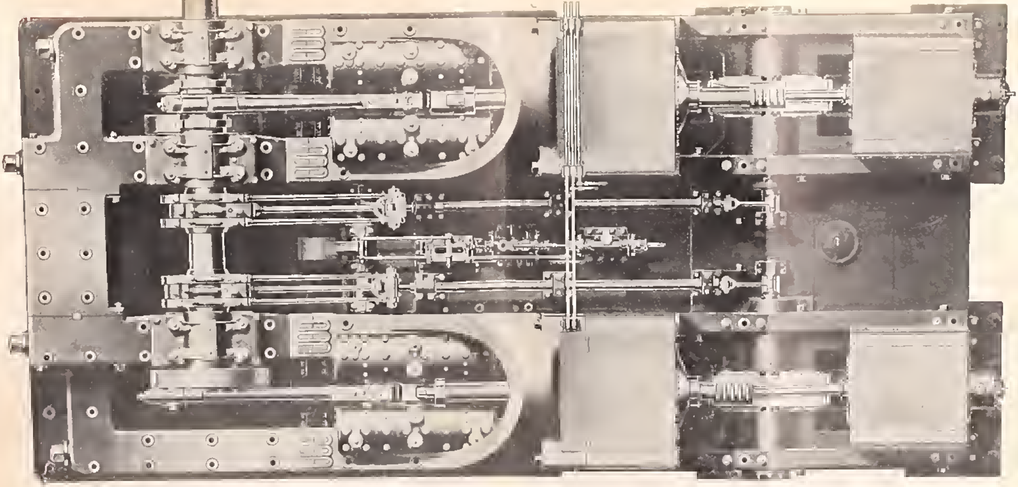
The engine frames are of box form, extremely heavy in construction, 36 ft. long, 12 ft. wide and 5 ft. high to center of shaft, except under the bearings, where flat reinforcements make a total height of 6 ft. 9 in. Each frame is in two pieces fastened together with four 3 in. fitted bolts and 27 shrink links, 2½ in. square. Additional fastening is secured by means of four forged steel reinforcing bolts, 9 in. diameter in body with upset ends, running lengthwise of the frames and located close up to, underneath, the bearings. The lower part of the frames are further reinforced directly below the main bearings with six heavy shrink links placed as near the bottom as possible.

Heavy distance pieces connect the main frames by means of bolts and maintain perfect alignment of same by use of fitted feather keys placed horizontally and vertically. The vertical keys show in Fig. 2. The rear distance piece carries the reversing gear.

The cast iron crosshead slides are bolted to the main frames and are arranged to permit overtravel of the crossheads without possibility of injury to the frames in the event of breakage of a piston rod or connecting rod.

The extension bed plates are of box form and are carried on four heavy cast iron legs extending down to the concrete foundation, each leg having a footing area of 80 sq. ft. The introduction of these legs, which take the place of concrete walls, permits of a flat foundation at the lower level, giving complete accessibility to all parts of the engine below the floor. These extension beds are connected by distance pieces carrying the intermediate crossheads and rock shaft brackets.

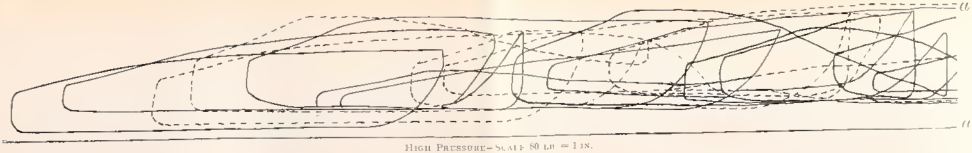
The cylinders are of close grained air furnace iron. Steam connections are 17 inch. In case of accident due to water or other causes the heads are free to break, avoiding injury to other parts of the engine. The pistons are steel castings, those in the high pressure cylinders having a total depth of 14 in., which is also the depth of the packing. The low pressure pistons are 18½ in. deep in the middle. The width of packing



PLAN OF 20 000 HORSE POWER ENGINE—MACKINTOSH, HEMPHILL & COMPANY, BUILDERS

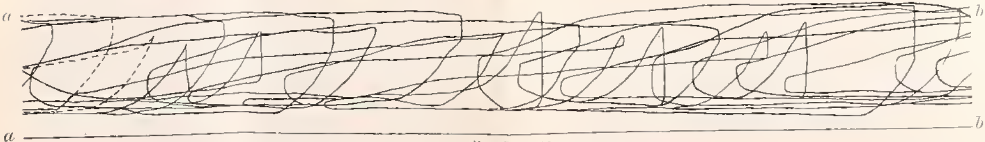
FIG. 2

SECTIONAL ELEVATION THRU CENTER LINE OF ENGINE

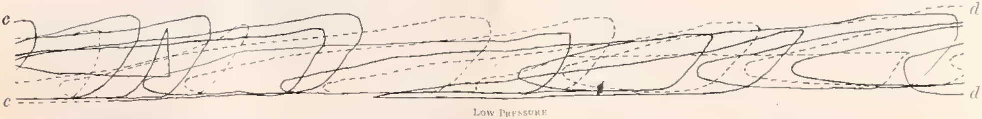


High Pressure—Scale 80 lb. = 1 in.

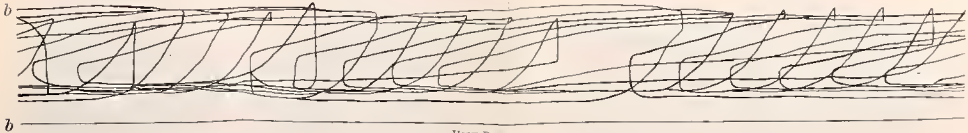
Low Pressure—Scale 30 lb. = 1 in.



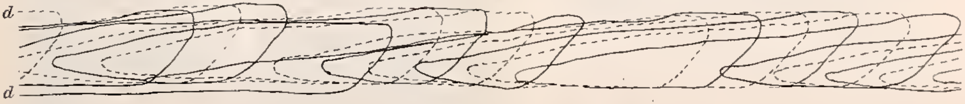
High Pressure



Low Pressure



High Pressure



Low Pressure

CONTINUOUS INDICATOR CARDS

in this case is only 6 in., as the weight of the piston is carried by the rods. The packings consist of bronze bull rings, inlaid with babbitt, the rings bearing directly on the cylinder walls and in the high pressure adjustment is by steel wedges. Cast iron spring rings with bronze keepers are fitted in each piston.

The method of attaching the low pressure cylinder to the engine frames is shown in Fig. 1. The rear ends of these cylinders are carried on the extension bed plates by means of legs cast on the cylinders. The high pressure cylinders have side flanges cast on their horizontal center lines which rest on the extension bed plates. These flanges are keyed at the center, allowing for expansion in either direction.

The low pressure piston rods are hollow steel forgings, oil tempered, 16 in. diameter. The high pressure rods are solid steel forgings 9 in. diameter. The connection of the high and low pressure rods is clearly shown in Fig. 1, nickel steel keys serving as fastenings for the rods. The straight fits on piston rods at the pistons and intermediate crossheads are also shown with shoulder bearings in each case. The rod fit in the main crosshead is also straight with key fastening.

The main crossheads are steel castings carrying 14 in. diameter by 15 in. long, forged steel pins; the shoes are bronze with babbitted faces 4½ ft. long by 15 in. wide. The intermediate crossheads are made in halves of steel castings. As indicated from the piston rod connections, these crossheads transmit no power, but serve only to support the rods and preserve alignment. A ring turned on the rod fitting into a groove in the crosshead transmits motion from the rod. Adjustment for wear is provided between all crossheads and shoes.

Continuous lubrication is provided, in connection with suitable filters and oil pumps. The engine weighs about 2 100 000 lbs., required 24 cars in shipping and was erected in the remarkably short time of four weeks. It has been in regular operation 24 hours a day since it was first started, about November 1st.

The continuous indicator cards shown in Fig. 4, were taken simultaneously from the high and low pressure cylinders

with engine operating under load conditions. The low pressure cards are placed directly below the corresponding portion of the high pressure cards.

After a thorough inspection of the engine, the party was conducted to the general office of the company, where an elaborate collation was spread. After spending a very pleasant social hour, Mr. George T. Barnsley and Mr. Thomas H. Johnson, in a few well chosen remarks, thanked the officials of the company for the very pleasant and profitable evening spent with them. The return trip was made in special trolley cars, arriving in the city at 10:45 P. M.

The arrangements were under the direction of the following officials of the company:

Homer D. Williams, General Superintendent.
E. J. Hamilton, Assistant General Superintendent.
J. M. Camp, Chief Chemist.
William Ahlen, Mechanical Engineer.
G. J. Bryen, Master Mechanic.
A. N. Diehl, Superintendent Blast Furnaces.
C. E. Maeder, Superintendent Rolling Department.
W. B. Trainor, Asst. Superintendent Rolling Department.
W. C. Jones, Superintendent of Mills Nos. 1, 2, 3 and 4.
Timothy Burns, Superintendent of 22-inch Mill.
S. G. Worton, Superintendent Open-Hearth Department.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXIV FEBRUARY, 1908 No. 1

ANNUAL MEETING.

The 28th Annual Meeting of the Engineers' Society of Western Pennsylvania was held at the Society rooms in the Fulton Building, January 14th, 1908, at 8:15 P. M., President Kintner presiding, 70 members being present.

The minutes of the last Annual Meeting having been printed in due course in the Proceedings, and there being no corrections, their reading was dispensed with.

ANNUAL REPORTS.

The following reports for the year were received:

Board of Direction, read by the Secretary.

Treasurer, read and explained by the Treasurer.

Finance Committee, read by the Chairman.

House Committee, read by the Chairman.

Entertainment Committee, read by the Chairman.

Publication Committee, read by the Secretary in the absence of the Chairman.

ELECTION.

Mr. Chester B. Albree, from the Tellers appointed to canvass the votes cast, made the following report:

Total number of votes cast	240
Irregular (not signed on outside envelope)	17
Legal votes	223

The following gentlemen were elected:

President, J. K. Lyons.

Vice President, for two years, E. K. Morse.

Treasurer, A. E. Frost.

Directors for three years, S. P. Grace, H. W. Craver.

The Chairman appointed Mr. Albree and Mr. H. J. Lewis to escort the newly-elected President to the chair.

The meeting then listened to an address from the retiring President, Mr. S. M. Kintner, on "The Alternating Current Railway Motor," illustrated by lantern slides; at the conclusion of which, on motion of Mr. Jno. N. Chester, seconded by Mr. Albree, a vote of appreciation of Mr. Kintner's efforts in behalf of the Society for the past year, was carried unanimously.

Adjourned at 10 P. M. EDMUND YARDLEY,
Secretary.

REPORT OF THE BOARD OF DIRECTION FOR 1908.

Meetings.

The Board has held twelve regular meetings during the year, the average attendance at which, including ex-officio members, was seven and a half.

The Society has held one annual meeting, ten regular monthly meetings, and two special meetings, at which the average attendance was seventy. Not only was this an increase over the average of 1906, but the later meetings seem to show a healthy increase over the earlier ones; due, no doubt, to increasing interest in the papers produced.

As usual, no meetings were held during July and August, and the corresponding Proceedings in August and September were not published.

Membership.

The actual membership on the roll of the Society December 31st, 1907, was 863. Divided as follows:

Active members (3 life members)		850
Honorary members		7
Juniors		6
		863

New members		46
Resumed membership		1
		47
Resignations	67	
Deaths	4	71
Decrease in membership		24

Income and Expenses.

The total income of the Society for the year from all sources was $13,118.63; the total disbursements, $13,258.85, or an excess of $140.22. This is due to members in arrears, from whom there is still due for 1907 alone $834.75. The income account accompanying the Treasurer's report shows the actual distribution of the receipts and expenses, and discloses the fact that the total available capital of the Society amounts to $9,277.75.

General.

The Society Rooms have been kept open on Saturday evenings during the year, and though the attendance is not large, it is fully justified by the interest of those attending, which interest is increasing.

The Board has established gold and silver medals to be awarded to the authors of papers read before the General Society during the year. These medals will be awarded in the near future for papers read in 1907.

EDMUND YARDLEY,
Secretary.

REPORT OF TREASURER.

Receipts from all sources	$13,118 63
Disbursements	13,258 85
Excess of disbursements	$ 140 22

Investments.

BUILDING FUND.	COST.
One, $1,000.00, Butler Water Company, 5 per cent. bond, No. 9, matures September 2, 1931	$ 1,025 00
PERMANENT FUND.	
Two, $1,000.00, Butler Water Company, 5 per cent. bonds, Nos. 317-318, mature October 1, 1939	2,020 00
Two, $1,000.00, Portsmouth, Berkeley & Suffolk Water Company, 5 per cent. bonds, No. 465-466, mature November 1, 1944	2,000 00
One, $1,000.00, Manufacturers Light & Heat, 6 per cent. bond, No. 442, Series K, matures May 1, 1914	1,010 00
One, $1,000.00, Manufacturers Light & Heat, 6 per cent. bond, No. 1183, matures September 2, 1909	1,010 00
Total, seven bonds	$ 7,065 00

Income Account, 1907.

RECEIPTS (NET)	1907	1906	Increase	Decrease
Advertising	$2,086 21	$1,508 47	$577 74	$...........
Banquet, Profit on	40 84	....	40 84	....
Back Dues	195 00	329 00	....	134 00
Dues for Current Year	5,449 00	5,684 04	....	235 04
Donations	1,899 50	1,266 35	633 15	135 00
Entrance Fees and Life	385 00	520 00	....	....
Interest and Discount	547 59	444 67	102 92	....
Reprints, Profit on	15 00	....	15 00	....
Society Badges, Profit on	9 25	....	9 25	....
Buttons and Junk sold	....	46 82	....	46 82
Total	$10,627 39	$9,799 35	$828 04	....

EXPENSES (NET)	1907	1906	Increase	Decrease
Administration	$3,120 98	$2,983 34	$137 64	$...........
Entertainment	102 95	88 53	14 42	....
Library	113 94	33 60	80 34	....
House	4,537 69	3,136 66	1,401 03	....
Society Meetings	319 30	411 07	....	91 77
Structural Section	79 10	102 35	....	23 25
Mechanical Section	65 25	150 25	....	85 00
Miscellaneous—Charter, Application Blanks, Medal Die	250 75	356 77	....	106 02
Proceedings	1,884 61	1,265 55	619 06	....
Membership List	317 29	272 75	44 54	....
Total Expenses	$10,791 86	$8,800 87	$1,990 99	....

Net Loss for Year 1907.. $164 47
Net Profit for Year 1906.. 998 48

Capital January 1st, 1907..$9,442 22
Deficit for 1907.. 164 47

Capital January 1st, 1908..$9,277 75

DETAILS OF CAPITAL.

ASSETS.		LIABILITIES.	
Bonds	$7,065 00	Dues for 1908 collected	38 00
Permanent Fund	1,326 84	Advance Payments	45 00
Building Fund	447 70	Balance	9,277 75
Bank Balance	257 46		
Petty Cash	250 00		
Society Buttons on hand	13 75		
	$9,360 75		$9,360 75

Respectfully submitted.

A. E. FROST,

Treasurer.

BOARD OF DIRECTION, JANUARY 11th, 1908.

The regular monthly meeting of the Board of Direction was held at the Society's Rooms, Fulton Building, Pittsburgh, Pa., Saturday, January 11th, 1908, at 8:00 P. M.

Present: Messrs. Lyons, Morse, Frost, Schellenberg, Handy, Riddle and the Secretary. In the absence of the President, Vice-President Lyons presided.

The minutes of the last meeting were read and approved.

Vouchers for December amounting to $786.95 were approved.

The Treasurer's report for 1907 was presented by Mr. Frost and received.

The Secretary reported some 35 members that were in arrears for two years or more. Final action in their case was deferred until the February meeting.

The report of the Publication Committee for 1907 was received.

The report of the Publication Committee, submitting Style Sheet was received and laid on the table for future action. The Secretary was directed to procure a number of copies of this sheet for distribution among the members of the Board.

The report of the committee on Percy F. Smith's extra bill was received and accepted and a voucher for the amount, $83.07, was ordered drawn.

The Secretary was directed to notify Mr. Smith that the Board would exercise its option and renew the contract with him for another year. It was further resolved that certain modifications of the contract were desirable for the sake of securing a clearer understanding of some of its provisions and that such modifications as were mutually satisfactory should be made.

The Secretary was authorized to continue the attendant on Saturday night indefinitely and to prepare a book in which

the Saturday night visitors might register their names for the information of the Board.

Adjourned.

EDMUND YARDLEY,
Secretary.

MEMBERSHIP

Changes of Address.

ALLEN. HARVEY, Pressed Steel Co., McKees Rocks, Pa.
BERG, H. A., Midland, Pa.,
BINNS, R. H., 223 Fourth Ave., Pittsburgh.
JONES, J. E., Illinois Steel Co., Chicago, Ills.
MUIR, JOHN J., Fort Wayne, Ind.
McGRAW, J. R., Brisbane Building, Buffalo, N. Y.
NELSON, A. H., Atlantic City, N. J.
RODGERS, E. H., 422 Dewey St., Mt. Oliver, Pittsburgh.
RUHE, C. H. W., Diamond Bank Building, Pittsburgh.
VINCENT, LEWIS, 416 Little St., Sewickley, Pa.

Resignations

ABBOTT, W. L.,
BACHTEL, S. R.,
BAKER, S. S.,
BODWELL, H, L.,
BRYAN, C. W.,
BUTLER, K. H.,
DAVIS, WM.,
DOWNTON, C. E.,
HALL, M. W.,
HOEM, OLE,
HOERLE, ED.,
HUNGERFORD, H. B.,
KAUFMAN, J. S.,
KENAH, R. L.,
LANDIS, J. W.,
LANE, A. A.,
McGRAW, T. H.,
McGAFFEY, M. W.,
McGREW, A. B.,
McMULLIN, F. V.,
REID, SAMUEL,
RICE, F. S.,
RICH, C. H.,
RICHARDSON, R. R.,
SMITH, W. H.,
STEINEMEYER, C. S.,
STOWELL, M. R.,
TENNEY, M. A.,
WHEELER, W. A.,
WORTHINGTON, CHAS.

Deaths

ANTES SNYDER, a charter member of the Society..................
....Wilkinsburg January 20, 1908

ANNUAL MEETING OF THE STRUCTURAL SECTION.

The annual meeting of the Structural Section was held at the Society's Rooms, Fulton Building, Pittsburgh, Tuesday, January 7, 1908, Chairman Khuen presiding.

The minutes of the last annual meeting were read and approved.

The retiring Chairman excused himself from making an address and called for a report from the Nominating Committee. L. J. Affelder, on behalf of the Nominating Committee, reported the following ticket for officers for the ensuing year:

E. W. Pittman, Chairman.

J. A. McEwen, Vice-Chairman.

E. Gerber, Willis Whited, H. S. Prichard, Directors.

On motion, the Secretary was instructed to cast the unanimous vote of the section in favor of the persons named.

The annual meeting then adjourned.

REGULAR MEETING OF STRUCTURAL SECTION.

Immediately following the annual meeting the regular monthly meeting was called to order by Chairman Khuen and Messrs. D. M. Howe and L. J. Affelder were appointed by the chair to escort the newly-elected Chairman to the platform.

The minutes of the last regular meeting having been published, the reading of them was dispensed with.

There being no further business before the Section, Mr. R. B. Woodworth, of the Carnegie Steel Company, read a paper on "New Forms of Steel for New Uses," which was discussed by Messrs. Khuen, Affelder, Blum, Stucki, McEwen and Preston.

At the suggestion of the Chairman, who remarked that this was one of the most interesting papers that has been read before the Section, a vote of thanks was unanimously given to Mr. Woodworth (who is not a member) for his very able and instructive paper.

Adjourned at 10:00 P. M., 34 members and visitors having been present.

SPECIAL MEETING OF THE SOCIETY.

A special meeting of the Society, in conjunction with the Mechanical Section, was held on January 14th, 1908, to listen to a paper on "Smoke Prevention," by Mr. Richard Krause, Supervising Engineer of the City of Cleveland.

Vice-President Lyons called the meeting to order, in the absence of the President, 80 members and visitors being present.

The paper was then read and discussed by Messrs. Rea, Chief Smoke Inspector of Pittsburgh; N. C. Wilson, Schellenberg, Albree, Hawley, Moore, Flanagan and Lewis.

On motion of Mr. Richard Hirsch, a vote of thanks was tendered to the speaker, who is not a member of the Society.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXIV — MARCH, 1908 — No. 2

REGULAR MONTHLY MEETING.

The 282nd monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Fulton Building on Tuesday, February 18th, at 8 o'clock P. M., President Lyons presiding, 70 members and visitors being present.

After the reading of the minutes of the previous meeting, Mr. William Metcalf, the first President of the Society, presented a paper on Heat Treatment of Steel Rails, followed by an interesting discussion.

The meeting adjourned at 10 P. M.

Edmund Yardley,
Secretary.

ANNUAL MEETING OF MECHANICAL SECTION.

The annual meeting of the Mechanical Section was held in the Society's rooms Tuesday, February 4th, 1908, at 8 o'clock P. M., Chairman Sumner B. Ely presiding.

The minutes of the last annual meeting were read, as published in the Proceedings, and approved.

The nominating committee recommended the following ticket for officers for the ensuing year:

G. E. Flanagan, Chairman.
E. H. Haslam, Vice-Chairman.
M. W. Hogle,
A. Stucki, — Directors.
L. C. Moore,

On motion, the Secretary was instructed to cast the unanimous vote of the Section in favor of the nominees named.

The annual meeting then adjourned.

REGULAR MEETING OF MECHANICAL SECTION.

Immediately after the annual meeting of the Mechanical Section, the regular bi-monthly meeting was called to order by Chairman G. E. Flanagan. After the reading and approval of the minutes of the previous bi-monthly meeting of the Section, Mr. Sumner B. Ely, the retiring Chairman, read a paper on "The Gas Engine's Probable Future." An interesting discussion followed.

The meeting adjourned at 10:00 P. M.

EDMUND YARDLEY,
Secretary.

BOARD OF DIRECTION, FEBRUARY 8, 1908.

The regular monthly meeting of the Board of Direction, held in the Society's rooms on Saturday, February 8, 1908, was called to order by President Lyons at 8:00 P. M., Messrs Lyons, Barnsley, Handy, Riddle, Schellenberg, Craver and the Secretary being present.

The minutes of the meeting of January 11th were read and approved.

The following applications for membership were favorably acted upon, to be elected at the next regular meeting of the Board:

W. H. KELLER. R. B. WOODWORTH.

Thirty-nine members, in arrears for two years' dues, were dropped from membership; resignations were accepted from three members of the Society to take effect at the end of 1908, and the dues of one member, for the year 1907, were remitted.

The death of Antes Snyder, a charter member of the Society, was announced, and Mr. F. Z. Schellenberg was requested to draw up a proper memoir.

Vouchers to the amount of $835.26 were approved.

A portion of the report of the Publication Committee relating to the style of publishing the Proceedings for the ensuing year was adopted.

The President announced the appointment of the several committees as published in the February issue of the Proceedings.

Adjourned at 10:00 P. M. EDMUND YARDLEY,
Secretary.

SPECIAL MEETING OF THE BOARD OF DIRECTION.

A special meeting of the Board of Direction was held at the Society's rooms on Monday, January 27, 1908, and called to order by President J. K. Lyons at 8 P. M., the following members of the Board being present: Messrs. Lyons, Kintner, Barnsley, Frost, Morse, Riddle, Grace and Schellenberg.

From among the applications for the position of Secretary for the year 1908, Mr. Richard Hirsch was placed in nomination and elected by the unanimous vote of the Board; formal transfer of the Secretaryship to take place February 29th. There being no further business the meeting adjourned.

WALTHER RIDDLE, Secretary Pro-Tem.

MEMBERSHIP.

The following new members were elected by the Board of Direction at the regular meeting held March 7th, 1908:

Active Members:

GLUCK, LEO, Assistant to President, Pittsburgh Coal Co., Pittsburgh.

KELLER, WM. H., Electrician and Mechanical Engineer, New River Colliers Co., Eccles, W. Va.

McKEE, JOHN SMITH, Sales Office Manager, Electric Controller and Supply Co., Pittsburgh.

WOODWORTH, ROBERT BELL, Engineer, Carnegie Steel Co., Pittsburgh.

Junior Member:

FAWELL, JOSEPH EDWARD, Draftsman, 363 South Negley Avenue, Pittsburgh.

CHANGES OF ADDRESS.

BARBOUR, G. H., Carnegie Steel Co., Pittsburgh.
DAVIES, T. P., Carnegie Steel Co., Duquesne, Pa.
LYONS, J. K., 5820 Baum Street, Pittsburgh.
MACFARREN, W. W., 1509 Arrott Building, Pittsburgh.
MARTELL, L. H., Anchor Packing Co., Philadelphia, Pa.
MARTIN, FERRIS B., Warsaw, N. Y.
McALEENAN, G. R., National Tube Co., South Lorain, O.
OPHULS, FRED, DeLa Vergne Machine Co., E. 139th St., New York.
RODGERS, E. H., American Sheet & Tin Plate Co., New Castle, Pa.
SITES, FRED R., 325 C Street, Oakmont, Pa.
SHUMAN, J. J., Jones & Laughlin Steel Co., Pittsburgh, Pa.
WILSON, B. C., 451 State Street, Brooklyn, N. Y.
WOOD, JOHN H., 7710 Waverly Street, Pittsburgh, Pa.
YARDLEY, EDMUND, Columbia Apartments, Taylor Avenue, Pittsburgh, Pa.

ADDRESSES WANTED.

The Secretary would like to have the present address of the following members:

JORDAHL, A.
PHILLIPS, G. W.
STRASBURGER, N. O.

TELEPHONE SERVICE.

For the convenience of members, special telephone service is being established in the Club Room.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXIV APRIL, 1908 No. 3

REGULAR MONTHLY MEETING.

The 283rd regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society's rooms, Fulton Building, Pittsburgh, Tuesday, March 17, 1908, at 8:00 P. M., President J. K. Lyons presiding, 50 members and visitors being present.

Minutes of the previous meeting were read and approved.

The Board of Direction reported the election of five new members at their meeting of March 7, 1908.

There being no further business before the Society, the paper of the evening, "Electrical Power in Iron and Steel Mills," was read by Mr. W. Edgar Reed, and was illustrated by a number of lantern slides. The discussion which followed was participated in by Messrs. Berentsen, Reed, Cronemeyer, Trinks, Haslam, Wiley, Skinner, Ellis, Lyons, Chessrown, Snyder, Bole and Blum.

Meeting adjourned at 10:35 P. M.

Richard Hirsch,
Secretary.

REGULAR MEETING OF STRUCTURAL SECTION.

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society's Rooms, Fulton Building, Tuesday, March 3rd, 1908, at 8:15 P. M., Vice Chairman J. A. McEwen presiding, 43 members and visitors being present.

Minutes of the previous meeting were read and approved.

A very interesting talk on the subject, "Retaining Walls," was given by Mr. Willis Whited, followed by a discussion participated in by Messrs. McEwen, Godfrey, Covell, Danforth, Lewis, Prichard, Stucki, Fisher, Moore, Ferguson and Whitman.

Meeting adjourned at 10:15 P. M.

RICHARD HIRSCH,
Secretary.

BOARD OF DIRECTION MARCH 7, 1908.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society's Rooms, Fulton Building, Pittsburgh, Saturday, March 7th, 1908, at 8:00 P. M., Messrs. Lyons, Barnsley, Craver, Grace, Handy, Frost, Schellenberg, Cummings and the Secretary, being present.

Minutes of the special meeting of the Board of Direction, held January 27th, and of the regular meeting held February 8th, 1908, were read and approved.

Five new members were elected, as per list published in the March Proceedings. The application of Mr. Norman S. Sprague, for membership, was favorably passed, to be finally acted upon at the April meeting of the Board.

The resignations of Messrs. Louis H. Flanders and M. A. Gilbert were accepted.

Disbursements made during the month of February, to the amount of $1,762.64, were approved.

Meeting adjourned at 10:00 P. M.

RICHARD HIRSCH, Secretary.

REGULAR MONTHLY MEETING.

The 284th regular monthly meeting of the Engineers' Society was held in the Society's Rooms, Fulton Building, Pittsburgh, Tuesday, April 21st, 1908, at 8:15 P. M., President J. K. Lyons presiding, 60 members and visitors being present.

The minutes of the previous meeting of the Society were read and approved.

Extracts were read from the minutes of the regular meeting of the Board of Direction held April 11th, and of the special meeting of the Board held April 17th, 1908.

No further business coming before the Society, the paper of the evening, "The Monongahela River; Some of its Characteristics, and Brief Sketch of Methods Undertaken for the Improvement of its Navigation," was read by Col. T. P. Roberts. The features of the paper were illustrated by numerous lantern slides, and the discussion was participated in by Maj. Newcomer, Messrs. Lyons, Yardley, Hirsch, Roberts, Hopkins, Lewis, Arras, and Brecht.

Meeting adjourned at 10:15 P. M.

RICHARD HIRSCH,
Secretary.

MECHANICAL SECTION.

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania, was held in the Society's Rooms, Fulton Building, Pittsburgh, Tuesday, April 7th, 1908, and called to order by Chairman G. E. Flanagan, at 8:15 P. M., 27 members and visitors being present.

The minutes of the previous meeting were read and approved, and no other business coming before the meeting, Mr. Jas. A. Baker read the paper of the evening, "Chains and Chain Making," which was followed by an interesting discussion participated in by Messrs. Wilson, Baker, Anderson, Albrec Moore, Winter, Hirsch, Nicholson, Danforth, Stucki and Godfrey.

Meeting adjourned at 10:10 P. M.

RICHARD HIRSCH,
Secretary.

BOARD OF DIRECTION, APRIL 11TH, 1908.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society's Rooms, Fulton Building, Pittsburgh, Saturday, April 11th, 1908, at 8:15 P. M., Messrs. Lyons, Barnsley, Cummings, Riddle, Craver, Handy and the Secretary, being present.

Minutes of the meeting of March 7th, were read and approved.

Mr. Norman S. Sprague was elected to active membership in the Society.

The following applications for membership were favorably passed, to be finally acted upon at the next regular meeting of the Board:

FERGUSON, CLARENCE A.	PHILLIPS, WM. R.
HEWITT, THOMAS E.	RALL, CHARLES R.
OTTESEN, FREDRIK.	TAYLOR, CHARLES E.

The resignation of Mr. Daniel Turpit was accepted.

The following amendment of Article III, Section 2, of the By-Laws, was proposed:

"Any person whose dues are more than three months in arrears shall be notified by the Secretary. Should the dues not be paid when they become six months in arrears, he shall lose the right to vote, to hold office, or to receive the Society's Proceedings. Should his dues become nine months in arrears, he shall again be notified in form prescribed by the Board, and if such dues become one year in arrears, he shall forfeit his connection with the Society. The Board shall have authority, for reasons deemed sufficient, to extend the time of payment, or remit, in part or in whole, the dues or the application of these penalties."

Disbursements to the amount of $647.68 were approved, and the payment of bills to the amount of $84.38 was authorized.

Meeting adjourned at 10:15 P. M.

RICHARD HIRSCH, Secretary.

SPECIAL MEETING OF THE BOARD OF DIRECTION APRIL 17TH, 1908.

A special meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held at the Society's Rooms, Fulton Building, Pittsburgh, Friday, April 17th, 1908, at 3:30 P. M., to discuss the advisability of taking some action relating to the conference called by President Roosevelt for May 13th, 14th and 15th, to consider matters relative to the Conservation of the Natural Resources of the United States. The meeting was attended by Messrs. Lyons, Barnsley, Riddle, Craver, Handy, Grace, Cummings, Schellenberg and the Secretary.

The following resolutions were unanimously adopted:

"Whereas, The Engineers' Society of Western Pennsylvania recognizes the fact, that the Natural Resources of the United States are being drawn upon at a rate which means their early and entire exhaustion; and that unless some means be taken to curtail the wanton waste of our timber, coal and other minerals, the people of this country, at no great distant future, will be confronted by conditions arising from the almost complete depletion of our natural resources; and that measures should be adopted to effect a more economical use of our standing timber, our coal, ores, oil and other minerals; and that definite and concerted action should be taken to preserve and replenish our forests, and to restore fertility to the soil long neglected and now worn out; and that a restoration of the forests will largely prevent the disastrous floods which are now washing away our fertile soil and leaving our lands bare and barren;

Be it Resolved, That the Engineers' Society of Western Pennsylvania extends to the President of the United States an expression of our appreciation of his earnestness which has prompted him to call the conference to be held on May 13th, 14th and 15th, 1908, and which we pray will result in such action on the part of Federal and State authorities as will con-

serve the resources of this great Nation for the uses of this and coming generations; and

Be it Resolved, That we also extend to the Governor of our Commonwealth an expression of the deep interest which we have in a matter of so great importance to the welfare of the whole people, and that we respectfully and earnestly urge Governor Stuart and those whom he has chosen as his advisers, to exert every possible effort to bring about some tangible result from the deliberations of the coming conference; results which will lead to an effective and unified action throughout the land; and

Be it Resolved, That copies of these resolutions be forwarded to the President of the United States, to the Governor of Pennsylvania, to our Senators and Representatives in Congress, to the Pittsburgh Chamber of Commerce, and to the daily press."

THE ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

RICHARD HIRSCH,
Secretary.

J. K. LYONS,
President.

[SEAL.]

Upon motion unanimously carried, the Secretary was directed to send to the President of the United States, to the Governor of Pennsylvania, to our Senators and Representatives in Congress, to the Pittsburgh Chamber of Commerce and to the public press, copies of the resolutions, accompanied by an appropriate letter containing references to the various papers relating to this general subject and read before the Society from time to time.

Meeting adjourned at 4:30 P. M.

RICHARD HIRSCH,
Secretary.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIV MAY, 1908 No. 4

REGULAR MONTHLY MEETING.

The 285th regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the Society's rooms, Fulton building, Pittsburgh, Tuesday, May 19, 1908, at 8:00 P. M., Vice-President George T. Barnsley presiding, 60 members and visitors being present.

The minutes of the previous meeting were read and approved.

The Board of Direction reported the election of six members.

No business coming before the meeting, the paper of the evening, "The Ohio River, a Brief Description of Its Principal Navigation Improvements, With Mention of Some of Its Characteristics," was read by Mr. J. W. Arras, assistant engineer in local charge of movable dams in the Pittsburgh district. The paper was illustrated by numerous lantern slides, and the discussion following was participated in by Messrs. Morse, Barnsley, Roberts, Leaf, Geegan, Chester, Arras and Newcomer.

Meeting adjourned at 10:15 P. M.

RICHARD HIRSCH,
Secretary.

REGULAR MEETING OF STRUCTURAL SECTION.

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society's rooms, Fulton building, Tuesday, May 5, 1908, at 8:15 P. M. Chairman E. W. Pittman presided, 18 members and visitors present.

The paper of the evening, "Wind Bracing in Buildings," written by Mr. Arthur L. Bobbs, was, in the absence of the author, read by Mr. Pittman. The stress diagrams referred to in the paper, were thrown upon the screen. Messrs. Woodworth, Hardie, McEwan, Wilkerson, Duckham, Pittman and Hirsch took part in the discussion.

Meeting adjourned at 9:35 P. M.

RICHARD HIRSCH,
Secretary.

BOARD OF DIRECTION, MAY 9, 1908.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held at the Society's rooms, Fulton building, Pittsburgh, Saturday, May 9, 1908, at 8:15 P. M., Vice-President George T. Barnsley presiding, and the following members being present: Messrs. Morse, Grace, Schellenberg, Riddle, Cummings, Craver and the Secretary.

The minutes of the meeting of April 11, were read and, after correction to include the name of Mr. F. Z. Schellenberg as being present, were approved.

The minutes of the special meeting of April 17, were read and, after correction, were approved.

The following named gentlemen were elected to active membership:

FERGUSON, CLARENCE A.
HEWITT, THOS. EDWIN
OTTESEN, FREDRIK
PHILLIPS, WM. RAYMOND
RALL, CHARLES RUDOLF
TAYLOR, CHAS. EDWARD

Applications for Membership.

Application for junior membership from Mr. Frederick Geary Sharra was favorably passed and ordered to be published in accordance with that Article in the By-Laws relating to election and membership.

Disbursements, during the month of April, to the amount of $623.11, were approved, and bills to the amount of $191.69 were ordered to be paid.

Meeting adjourned at 10:15 P. M.

RICHARD HIRSCH,
Secretary.

TRADE PUBLICATIONS—ANNOUNCEMENTS.

THE LUNKENHEIMER COMPANY, of Cincinnati, announces the issuance of their new '08 catalog. It is a cloth-bound book of 564 pages, (5x8), a revision of their 1906 edition, made necessary in order to classify new goods recently added to their product. The articles listed are well grouped and conveniently indexed; Section XV. contains some fifty pages of Tables and Useful Data. The book will be sent free to anyone interested in the Lunkenheimer product.

JENKINS BROS. announce the removal of their Chicago store from 31-33 North Canal street, to 226-228 Lake street, corner of Franklin street. Their New York location is 71 John street.

CHANGES OF ADDRESS.

BRIGEL, S. G., Land-Wharton Co., Pennsylvania Building, Philadelphia, Pa.

CONVERY, J. J., 2411 West Third St., Chester, Pa.

DAVIDSON, J. S., 561 Frick Annex, Pittsburgh.

GODDARD, H. W., Cessna & Goddard, Boston, Mass.

HAMPTON, W. H., 128 Minnick Court, Chicago, Ill.

HEGMAN, W. H., 1416 La Clair St., Swissvale, Pa.

HOVEY, R. L., La. & Ark. R. R., Texarkana, Ark.

PENDRY, W. R., 412 Herkimer St., Joliet, Ill.

RAUDENBUSCH, W. S., 239 Cumberland St., Lebanon, Pa.

ST. JOHN, E. R., 659 Maryland Ave., Pittsburgh.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXIV JUNE, 1908 No. 5

REGULAR MONTHLY MEETING.

The 286th regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the Society's rooms, Fulton building, Pittsburgh, Tuesday, June 16, 1908, at 8:00 P. M., Vice-President George T. Barnsley presiding, 58 members and visitors being present.

The minutes of the previous meeting were read and approved.

The Board of Direction reported the election of one junior member at the meeting held June 6th, and also the favorable consideration of six applicants for membership whose names will come before the Board for final action at its next meeting.

An amendment to the By-Laws—as noted on page 18, April issue—was also reported to the meeting, to be voted upon by the members of the Society by letter ballot.

No other business coming before the meeting, the paper of the evening, "Structural Shop Equipment," was read by Mr. G. P. Thomas, of the Standard Bridge Tool Company, Pittsburgh, Pa.

The discussion was participated in by Messrs. Albree, Prichard, Hirsch, Barnsley, Wilkerson, Danforth, Thomas, Flanagan, Thompson, Norton and Whitman.

A vote of thanks for Mr. Thomas' very interesting paper was unanimously passed by the Society.

After adjournment of the meeting at 9:20 P. M., the members spent a pleasant hour in social intercourse.

RICHARD HIRSCH,
Secretary.

REGULAR MEETING OF MECHANICAL SECTION.

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania, was held in the Society's rooms, Fulton building, Tuesday, June 2, 1908, at 8:15 P. M., Chairman G. E. Flanagan presiding, 18 members and visitors being present.

The paper of the evening, "Automatic Fire Protection," was read by Mr. W. A. Neracher, second vice-president of the General Fire Extinguisher Company, Warren, Ohio.

The discussion following the reading of the paper was participated in by Messrs. Flanagan, Trimble, Hirsch, Neracher, Hardy, Boyle, Schatz, Moore, and Hawley.

Meeting adjourned at 10:30 P. M.

RICHARD HIRSCH,
Secretary.

BOARD OF DIRECTION, JUNE 6, 1908.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society's rooms on Saturday, June 6, 1908, at 8:25 P. M., President J. K. Lyons and the following members being in attendance: Messrs. Barnsley, Craver, Schellenberg, Handy, Frost, Morse, Grace, and the Secretary.

The minutes of the meeting of May 9th were read and approved as read.

Mr. Frederick Geary Sharra was elected a junior member, and the following applications for membership were favorably passed upon and ordered to be published to the Society in accordance with that Article in the By-Laws relating to election and membership:

ACTIVE.

HENRY HARRER. HOWELL VAN BLARCOM.
FREDERICK WHITEFIELD WITHERELL.
EMIL HENSEN. CHARLES EDWARD LEFEBVRE.

JUNIOR.

JAMES M. SHADES.

The Secretary's report of the receipts and disbursements during the month of May which had been submitted to, and duly approved by the Finance Committee at its meeting held Saturday afternoon, June 6, 1908, was presented to, and approved by the Board. Disbursements during the month amounted to $822.43.

The amendment to the By-Laws given in full on page 18, (April issue), abstract of minutes, was ordered to be published to the Society, as required by the By-Laws.

The Board directed that the Society's rooms be closed at 5:00 P. M., except on Saturdays, when they will be kept open until 10:00 P. M.

Meeting adjourned at 10:30 P. M.

RICHARD HIRSCH,
Secretary.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIV OCTOBER, 1908 No. 7

REGULAR MONTHLY MEETING.

The 287th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society's rooms, Fulton Building, Pittsburgh, Tuesday, September 15, 1908, at 8:00 P. M., President James K. Lyons presiding.

The minutes of the last meeting were read and approved.

The Board of Direction reported the election of five gentlemen to Active membership and one to Junior membership in the Society, at the meeting held September 5th, and also the favorable consideration of nine applicants for membership whose names will come before the Board for final action at its next meeting.

No other business coming before the meeting the paper of the evening, "The Development of Telephony," was read by Mr. Sergius P. Grace, General Superintendent of Plant, Central District and Printing Telegraph Co., Pittsburgh.

The discussion was participated in by Messrs. H. W. Fisher, Snyder, Rall, Lyons, Wilkins, Tuttle, Martin, Moore, Feicht, Albree, Stucki, F. P. Fisher and Grace.

The meeting adjourned at 10:20 P. M.

RICHARD HIRSCH,
Secretary.

MEETING OF STRUCTURAL SECTION.

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Tuesday, September 1,

1908, at 8:15 P. M. Chairman E. W. Pittman presided, 21 members and visitors being present.

The minutes of the meeting of May 5th were read and approved.

The Chairman announced the resignation of the Secretary, effective September 1st, to be succeeded by Mr. Elmer K. Hiles.

No further business coming before the meeting Mr. William Martin read the paper of the evening, "Renewing Foundation of a Water Tank" on Blackhorse Hill, Pittsburgh.

The discussion following the reading of the paper was participated in by Messrs. Hawley, Knowles, Covell, Johnson, Judd, McEwen, Whitman, Hirsch, Pittman, Woodworth, Schellenberg and Martin.

The meeting adjourned at 9:15 P. M.

RICHARD HIRSCH,
Secretary.

MEETING OF MECHANICAL SECTION.

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society's rooms, Fulton Building, Tuesday, October 6, 1908, at 8:15 P. M., Chairman G. E. Flanagan presiding, 46 members and visitors being present.

Mr. Joshua L. Miner, Mill Chemist for the Alpha Portland Cement Co., Easton, Pa., read a paper: "The Strength of Concrete Joints." Mr. Chester B. Albree, Past President of the Society, read a paper: "The Simplification of Spring Formulae."

The discussion following the reading of the papers was participated in by Messrs. Wilkins, Winters, McClelland, Gerber, Stevens, Blum, Pittman, Miner, Flanagan, Johnson, Schaff, Ely, Wurts, Hale and Albree.

The meeting adjourned at 10:20 P. M.

RICHARD HIRSCH,
Secretary.

BOARD OF DIRECTION.

The regular meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Saturday, September 5, 1908, at 8:00 P. M., Vice President George T. Barnsley and the following members being present: Messrs. Schellenberg, Riddle, Craver, Grace, Frost, Cummings and the Secretary.

The minutes of the meeting of June 6th were read and approved.

The following gentlemen were elected to Active membership in the society:

Henry Harrer, Emil Hensen,
C. E. Lefebvre, F. W. Witherill,
Howell Van Blarcom,

Mr. J. M. Shades was elected a Junior member.

The applications for membership of the following gentlemen were favorably acted upon and ordered published to the Society in accordance with the By-Laws:

ACTIVE:

E. W. Beckeman, S. E. Duff,
E. B. Entwisle, A. R. Schulze,
Carroll Miller,

JUNIOR:

J. M. Harding, Francis Henderson,
K. W. Lemcke, S. B. Valentine,

Mr. H. H. Rankin, who had resigned from the Society, in good standing, was restored, at his request, to membership.

The Secretary's report of receipts and disbursements during the months of June, July and August, was presented and approved.

RICHARD HIRSCH,
Secretary.

EMPLOYMENT BULLETIN.

The Society has found it can do an important work as the medium for securing better positions for its members who desire them. The Secretary gives this his personal attention, and is desirous of receiving prompt notification both of positions open and of men available. Notices are not repeated except upon special request. The list of men available is made up of members of the Society, and these are on file, together with names of men not members of the Society, who are capable of filling responsible positions. Information will be sent on application.

POSITIONS OPEN.

01 Draftsman wanted by Isthmian Canal Commission. This man should be a citizen of the United States; graduate of electrical or mechanical courses from a technical college or university; at least thirty years of age, to have had two years in construction work either shop or field, in the branch of electrical or mechanical engineering, and one year to have been in responsible charge of same; two years' drafting, and have had at least one year of practical design in some one of the two above named branches of engineering, and must produce drawings which exhibit the character of work done; it is further desired that he be a member of one of the Engineering Societies. To receive $225.00 per month. Transportation free, New York to Isthmus. Six weeks leave, with pay, each year. Bachelor quarters furnished.

02 Draftsman wanted by Isthmian Canal Commission. This man should be a citizen of the United States; graduate of electrical or mechanical courses from a technical college or university; at least twenty-eight years of age; and have had two years of construction work, either shop or field in the branch of electrical, mechanical, or civil engineering; two years' drafting, and must produce drawings which exhibit his work. It is particularly desired that he have had experience in design of heavy machinery, and be familiar with shop practice of this class. He shall also present a certificate of qualifications from the various employers. The man having these qualifications to receive $200.00 per month. Transportation free, New York to Isthmus. Six weeks leave, with pay, each year. Bachelor quarters furnished.

03 Position is open for an Assistant to City Engineer in a city of 38,000 population in Central Pennsylvania. Salary $1,800.

MEN AVAILABLE.

1 Practical man, technically educated, desires position. Thirty-four years old. Seven years practical shop experience, five years experience in drawing room, and is familiar with general machine design. Willing to go anywhere.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXIV NOVEMBER, 1908 No. 8

REGULAR MONTHLY MEETING.

The 288th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, October 20, 1908, at 8:20 P. M., President James K. Lyons presiding, 70 members and visitors being present.

The minutes of the meeting of Sept. 15th were read and approved.

The Board of Direction reported the election of five Active and four Junior members at the meeting of October 10, 1908. Favorable action was also reported on two applications for membership.

No other business coming before the meeting the following papers were read:

"The Effect of Wind on Heating and Ventilation," by Mr. H. W. Whitten.

"Electrically Operated Brakes for Industrial Purposes," by Mr. H. A. Steen.

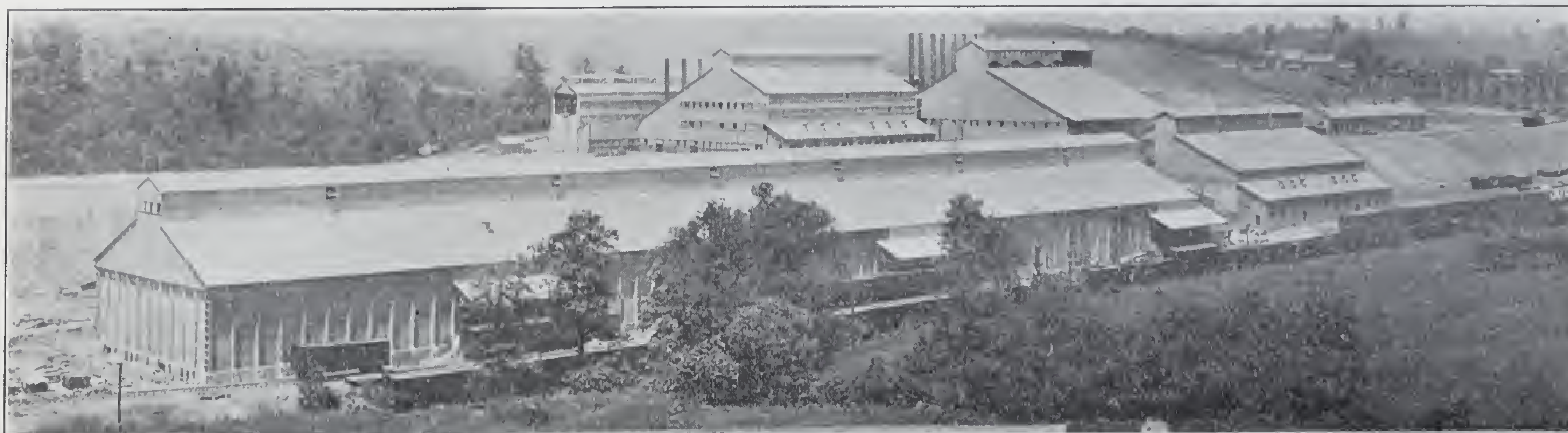
The discussion of Mr. Whitten's paper was participated in by Messrs. Stucki, Johnson, Esperon, Hirsch, Armstrong, Hiles, Flanagan, Wilkerson, Kennedy, and O'Neil.

Owing to the lateness of the hour the discussion of Mr. Steen's paper was postponed, with the author's concurrence, until a future meeting of the Society.

A vote of thanks to Messrs. Whitten and Steen for their very interesting papers was unanimously passed by the Society.

The meeting adjourned at 10:55 P. M.

Richard Hirsch,
Secretary.



Universal Portland Cement Company Works

Universal, Penna.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIV DECEMBER, 1908 No. 9

REGULAR MONTHLY MEETING.

The 289th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, November 17, 1908, at 8:00 P. M., President James K. Lyons presiding. 47 members and visitors being present.

The minutes of the meeting of October 20th were read and approved.

The Board of Direction reported the election of two Active members at the meeting of November 7, 1908. Favorable action was also reported on three applications for Active membership, and one application for Junior membership.

The report of the Nominating Committee which had been approved by the Board of Direction was read as follows:

President......... Geo. T. Barnsley
Vice-President.....Walther Riddle
Treasurer......... A. E. Frost
Directors........ { S. A. Taylor
{ J. N. Chester

This report was concurred in by all the members of the Nominating Committee except Mr. J. N. Chester, who was out of the city and not informed of their action.

No other business coming before the meeting the paper of the evening on "Mercury Rectifiers", was read by Mr. R. P. Jackson, of the Westinghouse Electric and Manufacturing Company.

The discussion following the reading of the paper was participated in by Messrs. Kintner, Taylor, Ely and Jackson.

The meeting adjourned at 9:30 P. M.

E. K. HILES, Secretary.

MEETING OF STRUCTURAL SECTION.

The regular bi-monthly meeting of the Structural Section of the Engineers Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, November 10, 1908, at 8:20 P. M., Chairman E. W. Pittman presided, 50 members and visitors being present.

The minutes of the meeting of September 1st were read and approved.

No further business coming before the meeting, the subject for discussion, "Lift Bridges," was introduced by Mr. H. S. Pritchard, with a paper describing various types of lift bridges.

Mr. Joseph B. Strauss of the Strauss Bascule and Concrete Bridge Co., presented discussion illustrated by lantern slides and a model of the Strauss bridge.

The Secretary read letters on the subject from the City Engineers' of Buffalo, Milwaukee, Chicago, Boston and Cleveland. Letters of discussion were read from Mr. Albert Lucius of New York, Mr. John L. Harrington of Waddell and Harrington, Kansas City, Mo., Mr. John P. Cowing of Cleveland and Mr. Edward Godfrey. Mr. John T. Dickerson, of the Scherzer Rolling Lift Bridge Co., Chicago, presented discussion illustrated by lantern slides. This was followed with a paper by Mr. John Ostrom, describing a bridge designed by the author in 1891.

The meeting adjourned at 10:45 P. M.

E. K. HILES, Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburgh, Saturday, October 10, 1908, at 7:45 P. M., President James K. Lyons presiding, the following members being present: Messrs. Barnsley, Kintner, Schellenberg, Riddle, Grace, Frost, Craver, Cummings and the Secretary.

The minutes of the last meeting were read and approved.

The application of the following gentlemen having been favorably passed upon by the Board at the meeting of September 5th, and regularly published to the Society, were duly elected to membership:

ACTIVE

E. B. Entwisle	S. E. Duff
E. W. Beckeman	A. R. Schulze

Carroll Miller

JUNIOR

K. W. Lemcke	Francis Henderson
J. M. Harding	S. B. Valentine

The applications of the following gentlemen were favorably acted upon:

Robert M. Greene E. K. Hiles

The requests for restoration to membership of H. C. Gould and M. A. Smith were favorably passed upon and their names ordered placed upon the Society rolls.

The report of the Secretary showing the financial condition of the Society at the close of business September 30, having previously been audited by the Financial Committee, was approved and the bills ordered paid.

RICHARD HIRSCH, Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburgh, Saturday, November 7, 1908, at 7:15 P. M., President James K. Lyons presiding, the following members being present: Messrs. Barnsley, Riddle, Handy, Schellenberg, Grace, Craver, Frost, Morse and the Secretary.

The minutes of the last meeting were read and approved.

The applications of the following gentlemen having been favorably passed upon by the Board at the meeting of Octo-

ber 10th, and regularly published to the Society, they were duly elected to membership:

R. M. Greene E. K. Hiles

The applications of the following gentlemen were favorably acted upon:

ACTIVE

Frederick G. Clapp Dwight T. Randall George P. Thomas

JUNIOR

Peter D. Woods

The requests for restoration to membership of Weaver H. Rodgers and R. W. Grange, Jr., were favorably passed upon and their names ordered placed on the Society rolls.

President Lyons appointed Messrs. Geo. T. Barnsley and E. K. Morse as delegates to represent the Society at the American Mining Congress, to be held in Pittsburgh on December 2nd, 3rd, 4th and 5th.

The report of the Secretary showing the financial condition of the Society at the close of business October 31st, having previously been audited by the Financial Committee, was approved and bills ordered paid.

The Secretary presented his resignation in the following letter:

To the President and Members of the Board of Direction of the Engineers' Society of Western Pennsylvania.

Gentlemen:

I herewith offer my resignation as Secretary of the Society, effective this date. In taking this action, I desire to express my appreciation of the very pleasant relations existing between the members of the Board and myself, and to assure you of my continued interest in the welfare of the Society.

Respectfully submitted,

(Signed) Richard Hirsch.

The Secretary's resignation was accepted with regret, the members of the Board of Direction expressing their appreciation of Mr. Hirsch's very efficient and loyal services to the Society during his term of office.

E. K. Hiles was elected Secretary of the Society for the unexpired term.

E. K. Hiles, Secretary.

ABSTRACT OF MINUTES

Engineers' Society of Western Pennsylvania

Vol. XXIV JANUARY, 1909 No. 10

REGULAR MONTHLY MEETING

The 290th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, December 15, 1908, at 8:15 P. M. The meeting was called to order by President J. K. Lyons, 93 members and visitors being present.

The minutes of the meeting of November 17th were read and approved.

The Board of Direction reported the election of three Active Members and one Junior at the meeting of December 5, 1908. Favorable action was also reported on nine applications for Active membership and one application for Junior membership. A. K. Ashworth, who had resigned in good standing, was restored to membership at his request.

The death of William Robert Browne, on September 3, 1908, was announced.

The inspection trip arranged through the courtesy of the officials of the Duquesne Works of the Carnegie Steel Company for Friday evening, December 18th, was announced by Geo. T. Barnsley, of the Entertainment Committee.

No other business coming before the meeting, the paper of the evening on "The Corrosion of Iron and Steel" was read by Alfred Sang.

The discussion following the reading of the paper was participated in by Messrs. Speller, Stahl, Woodworth, Unger, Whited, Flanagan, Handy, Gulick, Snyder and Sang.

The meeting adjourned at 10:55 P. M.

E. K. Hiles, Secretary.

MEETING OF MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms in the Fulton Building, Pittsburgh, Tuesday, December 1, 1908, at 8:15 P. M., Chairman G. E. Flanagan presiding, 55 members and visitors being present.

The minutes of the meeting of October 6th were read and approved.

On motion, Chairman Flanagan appointed the following gentlemen on the Nominating Committee:

J. L. Klindworth, S. B. Ely and L. C. Moore.

No fufther business coming before the meeting the Secretary read a letter from Mr. W. M. Kinney, advising that it would be impossible for him to be present to read a paper on the Manufacture of Portland Cement, announced for the evening, owing to business exigencies requiring his presence in New York.

A special program for the evening was arranged the day before through the courtesy of several members as follows:

J. W. Cruikshank read a paper on "Recent Improvements in the Manufacture of Plate Glass."

W. C. Hawley, Chester B. Albree, E. D. Leland and others responded with descriptions of novel designs and experiences in engineering work.

The discussion of Mr. Cruikshank's paper was participated in by Messrs. Leland, Godfrey, Henderson, Whited, Flanagan and Cruikshank.

The meeting adjourned at 10:20 P. M.

E. K. Hiles, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Saturday, December 5, 1908, at 8:15 P. M., President James K. Lyons presiding, the following members being present: Messrs.

Barnsley, Riddle, Handy, Schellenberg, Craver, Frost and Morse.

The minutes of the last meeting were read and approved.

The applications of the following gentlemen, having been favorably passed upon by the Board at the meeting of November 7, 1908, and regularly published to the Society, were duly elected to membership:

ACTIVE

Frederick G. Clapp — Dwight T. Randall

George P. Thomas

JUNIOR

Peter D. Woods

The applications of the following gentlemen were favorably acted upon:

ACTIVE

John T. Barr	John A. Ferguson
A. H. Helander	S. M. Kier
E. J. K. Mason	J. M. Milliken
Donald McNeil	P. M. Snoeberger

Thomas W. Smith

JUNIOR

Homer N. Bliss

The request of A. K. Ashworth, for restoration to membership, was favorably passed upon and his name ordered placed on the Society rolls, January 1, 1909.

The report of the Secretary, showing the financial condition of the Society at the close of business November 30th, was approved and bills ordered paid.

E. K. Hiles, Secretary.

EMPLOYMENT BULLETIN.

The Society has found it can do an important work as the medium for securing better positions for its members who desire them. The Secretary gives this his personal attention, and is desirous of receiving prompt notification both of positions open and of men available. Notices are not repeated except upon special request. The list of men available is made up of members of the Society, and these are on file, together with names of men not members of the Society, who are capable of filling responsible positions. Information will be sent on application.

POSITIONS OPEN.

06 Wanted: A capable young man, technical graduate, for assistant to superintendent of steam engineering department of steel works. Experienced man desired. Also, young man to learn the work.

07 Wanted: Graduate of technical school with some training in chemistry, for position in gas works.

08 Young engineer with degree from electrical college, electrical or mechanical, and with a liking for technical research rather than active engineering work. Ability to read French and German are essential.

MEN AVAILABLE.

7 Young man desires position with contracting company, either inside or outside work. Two and one half years' machine shop experience, three years railroad and city survey work and electrical construction.

8 Chemist and Metallurgist, technical education, 15 years experience, desires high grade laboratory position or other employment where scientific knowledge would be valuable. Prefer position in or near industrial and educational center.

9 Draftsman desires position on bridge or structural work. Technical education. Six years experience in detailing, checking, designing, estimating and erecting. At present employed on bridge designs. Best references furnished.

10 Technical graduate, associate member A. S. M. E., desires position in Pittsburgh. Experienced in organizing, systematizing, estimating, inspecting machinery, fuel economy, etc. Familiar with modern systems of cost keeping, capable of handling men and getting results on construction work, or in engineering department. Experience for last eight years has been principally in steel plants.

11 A recent graduate of an eastern technical school, with experience on street grading, sewers, water-line, water-works, plain and reinforced concrete and mill building construction, wants a position with engineering firm or contractor.

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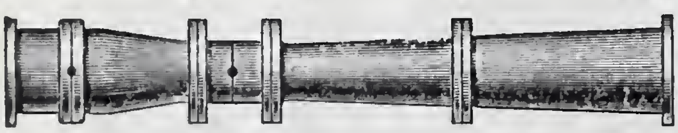

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DISCUSSION OF PAPERS.

Members of the Society and also other readers of the Proceedings are urged to send to the Secretary written discussion of papers after publication, which will be printed in succeeding issues of the Proceedings. We believe that much valuable information may be presented in this way and it is hoped that this feature of written discussion may be made a prominent one in the Proceedings.

ENGINEERING DATA.

The Publication Committee solicits contributions of engineering data for publication in the Proceedings. Formulas, Tables and Notes which are of everyday use and which are not found in the standard hand-books, are especially desired. The Committee believes that there is much valuable material in the hands of various members which should be available to all and that its publication would be very useful. Credit will be given for all contributions. Send data to the Secretary.

Space in the Proceedings will be given to members desiring information of an engineering nature.

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